APPENDIX D
NOISE IMPACT ASSESSMENT

Na Pua Makani Wind Farm

Honolulu County, Hawaii

Prepared for

CHAMPLIN/GEI WIND HOLDINGS, LLC

Champlin / GEI Wind Holdings, LLC
2020 Alameda Padre Serra, Ste. 123
Santa Barbara, CA 93103

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TETRA TECH

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1.0 INTRODUCTION

Champlin/GEI Wind Holdings, LLC (Champlin) is proposing to construct and operate the Na Pua Makani Wind Energy Project (the "Project") in Honolulu County, Hawaii. The proposed Project would implement one of two wind turbine generator (WTG) models, quantity, mega-watt (MW), hub-height and rotor diameter as shown in Table 1:

Table 1. Project WTGs under Consideration

Model	Quantity Alternative 2	Quantity Alternative 3	MW Output per WTG	Hub-height (m)	Rotor Diameter (m)
Vestas V110-2.0	2	2	2.0	80	110
Siemens SWT 3.0-113	8	10	3.0	92.5	113

Vestas 2013, Siemens 2013

The Project design configurations under consideration translate to a potential power output of approximately 25 to 42 MW, depending on WTG type and quantity. This noise impact assessment provides a description of the existing acoustic environment, noise impact criteria, acoustic analysis methodology, construction and operational noise levels, and conclusions and mitigation recommendations.

1.1 ENVIRONMENTAL NOISE DESCRIPTORS

Sound levels are presented on a logarithmic scale to account for the large range of acoustic pressures that the human ear is exposed to and is expressed in units of decibels (dB). A decibel is defined as the ratio between a measured value and a reference value usually corresponding to the lower threshold of human hearing defined as 20 micropascals (μPa). Broadband sound includes sound energy summed across the entire audible frequency spectrum. In addition to broadband sound pressure levels, analysis of the various frequency components of the sound spectrum can be completed to determine tonal characteristics. The unit of frequency is Hertz (Hz), and the limit of human hearing is from 20 Hz to 20,000 Hz. WTGs generally produce mechanical sound at a frequency of 20-30 Hz and a "whooshing" aerodynamic sound in the range of 200-1000 Hz (National Health and Medical Research Council 2013). Typically the frequency analysis for an industrial noise source, such as WTGs, examines 11 octave (or 33 1/3-octave) bands ranging from 16 Hz (low) to 16,000 Hz (high). One third (1/3) octave bands take these octave bands and split them into three, providing a higher resolution and a more detailed description of the frequency content of the sound. Since the human ear does not perceive every frequency with equal loudness, spectrally varying sounds are often adjusted with a weighting filter. The A-weighted filter is applied to compensate for the frequency response of the human auditory system. Existing sound exposure in the Na Pua Makani Wind Farm acoustic analysis area are reported in A-weighted decibels (dBA).

An inherent property of the logarithmic decibel scale is that the sound pressure levels of two separate sources are not directly additive. For example, if a sound of 50 dBA is added to another sound of 50 dBA, the result is a 3-decibel increase (or 53 dBA), not an arithmetic doubling of 100 dBA. The human ear does not perceive changes in the sound pressure level as equal changes in loudness. Scientific research demonstrates that the following general relationships hold between sound level and human perception for two sound levels with the same or very similar frequency characteristics:

- 1 dBA is the practically achievable limit of the accuracy of sound measurement systems and corresponds to an approximate 10 percent variation in sound pressure. A 1 dBA increase or decrease is a non-perceptible change in sound.
- 3 dBA increase or decrease is a doubling (or halving) of acoustic energy and it corresponds to the threshold of perceptibility of change in a laboratory environment. In practice, the average person is not able to distinguish a 3 dBA difference in environmental sound outdoors.
- 5 dBA increase or decrease is described as a perceptible change in sound level and is a discernable change in an outdoor environment.
- 10 dBA increase or decrease is a tenfold increase or decrease in acoustic energy but is perceived as a doubling or halving in sound (i.e., the average person will judge a 10 dBA change in sound level to be twice or half as loud).

To account for the time-varying nature of environmental noise, a single descriptor known as the equivalent sound level (L_{eq}) is often used. The L_{eq} value is the sound energy average over the complete measurement period. It is defined as the steady, continuous sound level over a specified time that has the same acoustic energy as the actual varying sound levels over the same time. The metrics commonly used for environmental sound studies, including the L_{eq}, are reported as dBA (A-weighted decibels) which is a frequency weighting curve that reflects the response of the human ear to sound frequencies across the entire audible frequency range. The equivalent sound level has been shown to provide both an effective and uniform method for describing time-varying sound levels and is widely used in acoustic assessments of wind energy facilities.

Several other statistical descriptors can also be assessed to provide additional understanding of the existing soundscapes. The statistical sound levels (L_n) provide the sound level exceeded for that percentage of time over the given measurement period. An L_{10} level is often referred to as the intrusive noise level and is the A weighted sound level that is exceeded for 10 percent of the time during a specified measurement period. Perhaps more useful is the L_{90} level, which is the A-weighted sound level that is exceeded for 90 percent of the time during the measurement time period. The L_{90} can be thought of as the quietest 10 percent of any time period and is often referred to as the residual sound level and can be an indicator of the potential of audibility for a new sound source. The L_{max} is the maximum sound level during the measurement period and the L_{min} is the minimum sound levels during the measurement period. Estimates of noise sources and outdoor acoustic environments, and the comparison of relative loudness are presented in Table 2. Table 3 provides additional reference information on acoustic terminology.

Table 2. Sound Pressure Levels (L_P) and Relative Loudness of Typical Noise Sources and Soundscapes

Noise Source or Activity	Sound Level (dBA)	Subjective Impression	Relative Loudness (perception of different sound levels)
Jet aircraft takeoff from carrier (50 ft)	140	Threshold of pain	64 times as loud
50-hp siren (100 ft)	130		32 times as loud
Loud rock concert near stage or Jet takeoff (200 ft)	120	Uncomfortably loud	16 times as loud
Float plane takeoff (100 ft)	110		8 times as loud
Jet takeoff (2,000 ft)	100	Very loud	4 times as loud
Heavy truck or motorcycle (25 ft)	90		2 times as loud
Garbage disposal, food blender (2 ft), or Pneumatic drill (50 ft)	80	Loud	Reference loudness
Vacuum cleaner (10 ft)	70	Moderate	1/2 as loud
Passenger car at 65 mph (25 ft)	65		
Large store air-conditioning unit (20 ft)	60		1/4 as loud
Light auto traffic (100 ft)	50	Quiet	1/8 as loud
Quiet rural residential area with no activity	45		
Bedroom or quiet living room or Bird calls	40	Faint	1/16 as loud
Typical wilderness area	35		
Quiet library, soft whisper (15 ft)	30	Very quiet	1/32 as loud
Wilderness with no wind or animal activity	25	Extremely quiet	
High-quality recording studio	20		1/64 as loud
Acoustic test chamber	10	Just audible	
	0	Threshold of hearing	

Adapted from: Beranek (1988) and USEPA (1971a)

Table 3. Acoustic Terms and Definitions

Term	Definition
Noise	Unwanted sound dependent on level, character, frequency or pitch, time of day, and sensitivity and perception of the listener. This word adds the subjective response of humans to the physical phenomenon of sound. It is commonly used when negative effects on people are known to occur.
Sound Pressure Level (L_P)	Pressure fluctuations in a medium. Sound pressure is measured in decibels referenced to 20 micropascals, the approximate threshold of human perception to sound at 1000 Hz.
Sound Power Level (L_W)	The total acoustic power of a noise source measured in decibels referenced to picowatts (one trillionth of a watt). Equipment specifications are provided by equipment manufacturers as sound power as it is independent of the environment in which it is located. A sound level meter does not directly measure sound power.
Frequency (Hz)	The rate of oscillation of a sound, measured in units of Hertz (Hz) or kilohertz (kHz). One hundred Hz is a rate of one hundred times (or cycles) per second. The frequency of a sound is the property perceived as pitch. For comparative purposes, the lowest note on a full range piano is approximately 32 Hz and middle C is 261 Hz.

Table 3. Acoustic Terms and Definitions

Term	Definition
A-Weighted Decibel (dBA)	Environmental sound is typically composed of acoustic energy across all frequencies (Hz). To compensate for the auditory frequency response of the human ear, an A-weighting filter is commonly used for describing environmental sound levels. Sound levels that are A-weighted are presented as dBA in this report.
Propagation and Attenuation	Propagation is the decrease in amplitude of an acoustic signal due to geometric spreading losses with increased distance from the source. Additional sound attenuation factors include air absorption, terrain effects, sound interaction with the ground, diffraction of sound around objects and topographical features, foliage, and meteorological conditions including wind velocity, temperature, humidity and atmospheric conditions.
Octave Bands	The audible range of humans spans from 20 to 20,000 Hertz and is typically divided into octave band center frequencies (Hz) ranging from 31 to 8,000 Hz.
Broadband Sound	The audible range of humans spans from 20 to 20,000 Hz and is typically divided into center frequencies ranging from 31 to 8,000 Hz.
Masking	Interference in the perception of one sound by the presence of another sound. At elevated wind speeds, leaf rustle and noise made by the wind itself can mask wind turbine sound levels, which remain relatively constant.
Low Frequency Noise (LFN)	The frequency range of 20 to 200 Hz is typically defined as low frequency noise. Studies have shown that low frequency sound from modern wind turbines is generally below the threshold of human perception at standard setback distances.
Infrasound (IS)	The frequency range of infrasound is normally defined as below 20 Hz. Infrasound from wind turbines are significantly below recognized thresholds for both human perceptibility and standardized health.

Note: Compiled by Tetra Tech from multiple technical and engineering resources.

1.2 LOW FREQUENCY NOISE AND INFRASOUND

Low frequency noise (LFN) and infrasound (IS) are defined by the frequency ranges they represent. LFN comprises noise in the audible human frequency ranges from 20 Hz to 200 Hz. IS represents the frequencies below 20 Hz that while typically inaudible to humans, if the amplitude of IS is very high, for example at least 80 or above for frequencies under 20 Hz and 103 dB or above for 5 Hz, it may be detectible to humans (Massachusetts Department of Public Health or MDPH 2012). Studies have shown that pain from infrasound can result when sound levels are 165 dB or above at 2 Hz and 145 dB or above at 20 Hz (MDPH 2012).

Existing non-WTG related LFN and IS are apparent in most, if not all, environmental settings. The magnitude of these existing background LFN/IS varies, but can be of sufficient strength in to mask much, or all of the LFN and IS from WTGs. Common background natural sound sources of LFN and IS include wind interacting with vegetation in the surrounding environment and ocean waves hitting shores. Additionally, a common anthropogenic sound source with LFN and IS components is roadway noise.

Outside of sleep disturbance from audible noise from WTGs, health effects have not been scientifically demonstrated as a result of low frequency noise from WTGs (MDPH 2012). Additionally, available evidence demonstrates there are no health effects from WTGs infrasound (NHMRC 2013).

2.0 PROJECT NOISE CRITERIA AND GUIDELINES

A review of noise regulations and guideline criteria applicable to the Project was completed at the federal, state, and county level. The Noise Control Act of 1972, along with its subsequent amendments (Quiet Communities Act of 1978 [42 USC 4901-4918]), delegates the authority to regulate environmental noise to each state. No county regulations were found but federal EPA guidelines and the State of Hawaii provide noise thresholds and guidelines applicable to the Project. Additionally, there are no federal, state, or local regulations or guidelines for LFN and IS; however, to provide a framework for assessing potential impacts from operational LFN and IS American National Standards Institute (ANSI) have been identified. Additionally, the United Kingdom (UK) Department of Environment, Food, and Rural Affairs (DEFRA) has proposed LFN 1/3-octave band criteria guidelines which are included in this report to provide another set of guidelines for which to compare against.

2.1 U.S. ENVIRONMENTAL PROTECTION AGENCY

In 1974, the U.S. Environmental Protection Agency (EPA) published Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety (EPA 1974). This report represents the only published study that includes a large database of community reaction to noise to which a proposed project can be readily compared. The EPA has developed widely accepted recommendations for long term exposure to environmental noise with the goal of protecting public health and safety. The publication evaluates the effects of environmental noise with respect to health and safety, and provides information for state and local governments to use in developing their own ambient noise standards. For outdoor residential areas and other locations in which quiet is a basis for use, the recommended EPA guideline is a day-night sound level (L_{dn}) of 55 dBA. The EPA also suggests an L_{eq}(24) of 70 dBA (24-hour) limit to avoid adverse effects on public health and safety at publicly accessible property lines or extents of work areas where extended periods of public exposure are possible. The EPA cause-and-effect criteria limits are summarized in Table 4.

Table 4. Summary of EPA Cause and Effect Noise Levels

Location	Level	Effect
All public accessible areas with prolonged exposure	70 dBA $L_{eq(24)}$	Safety
Outdoor at residential structure and other noise sensitive receptors where a large amount of time is spent	55 dBA L_{dn}	Protection against annoyance and activity interference
Outdoor areas where limited amounts of time are spent, e.g., park areas, school yards, golf courses, etc.	55 dBA $L_{eq(24)}$	
Indoor residential	45 dBA L_{dn}	
Indoor non-residential	55 dBA $L_{eq(24)}$	

Source: EPA 1974.

2.2 STATE OF HAWAII COMMUNITY NOISE REGULATIONS

The state of Hawaii regulates noise through the Hawaii Administrative Rule (HAR), Title 11, Chapter 46, and “Community Noise Control”, promulgated on September 11, 1996 and limits sound generated by new or expanded developments. The Hawaii Community Noise Regulations (HAR 11-46) provide for the prevention, control, and abatement of noise pollution in the State. The purpose of these rules is to “provide for the prevention, control, and abatement of noise pollution in the State from the following noise sources: stationary noise sources; and equipment related to agricultural, construction, and industrial activities" (HAR 11-46). Sound from routine ongoing maintenance activities is considered part of routine operation and the combined total of the ongoing maintenance and routine operation are subject to the sound level limits. However, the Community Noise Control Regulation is not applicable to most moving sources, i.e. transportation and vehicular movements. Sound from Project construction and the occasional, major equipment overhauls is regulated as construction activity.

The Hawaii noise limits due to stationary sources are provided by three receiving zoning class districts and time periods and are enforceable at the facility property boundaries. For mixed zoning districts, the primary land use designation is used to determine the applicable zoning district class and maximum permissible sound level. For the purposes of identifying impact conditions, Class A use on Class C Land has been defined at the residential structure, i.e. agricultural portions of the surrounding properties were considered Class C receivers and the residences considered Class A receivers. This is considered a conservative regulatory assessment approach.

As wind energy generation projects may operate at any time during the day or night, the more stringent nighttime permissible sound level will become the controlling limit. The daytime and nighttime maximum permissible noise limits are provided in dBA according to zoning districts in Table 5. The Hawaii noise limits are assumed to be absolute and independent of the existing acoustic environment; therefore, no baseline sound survey is required to assess conformity.

Table 5. Hawaii Maximum Permissible Sound Levels by Zoning District

Receiving Zoning Class District	Maximum Permissible Sound Level Daytime (7:00am – 10:00pm)	Maximum Permissible Sound Level Nighttime (10:00pm – 7:00am)
Class A Zoning districts include all areas equivalent to land zoned residential, conservation, preservation, public space, or similar type.	55	45
Class B Zoning districts include all areas equivalent to lands zoned for multi-family dwellings, apartment, business, commercial, hotel, resort, or similar type.	60	50
Class C Zoning districts include all areas equivalent to lands zoned agriculture, county, industrial, or similar type.	70	70

Source: Hawaii Administrative Rules §11-46, "Community Noise Control"

The maximum permissible sound levels are assessed and at any point at or beyond the property line of the facility. Noise levels may exceed the prescribed limits up to 10 percent of the time within any 20-minute period. Sound level for impulsive noise, as measured with a fast meter response, is 10 dBA above the maximum permissible sound levels for the given receiving zoning class district. Pursuant to HAR 11-46-7, and HAR 11-48-8 a permit may be obtained for operation of an excessive noise source beyond the maximum permissible sound levels. Factors that are considered in granting of such permits include whether the activity is in the public interest and whether the best available noise control technology is being employed. The standard provides further exemptions to these limits and further guidance on application, compliance procedures and penalties. The State Department of Health (SDOH) is responsible for the implementation, administration, and enforcement of the statutes.

2.3 LOW FREQUENCY NOISE AND INFRASOUND GUIDELINES

In the absence of LFN and IS noise regulations or guidelines some wind turbine acoustic studies have referenced a variety of guidelines and other country's regulations to assess the potential for impacts (O'Neal 2011). ANSI provides guidelines for outdoor LFN and IS levels via ANSI S12.9 Parts 4 and 5. Additionally, DEFRA provides guidelines for LFN that are used in the UK.

2.3.1 ANSI S12.9 Part 4

The ANSI S12.9 Part 4 (ANSI 2005) provides guidelines for determining annoyance from sound propagating outdoors. Annex D of ANSI S12.9 Part 4 includes methods for assessing environmental sounds with strong low-frequency content. Annoyance is found to be minimal when sound levels in the low frequency midband frequencies of 16 – 63 Hz are less than 65 dB, which corresponds to the threshold for the onset of impacts in these lower frequencies. Part 4 also states that LFN passes through structures with relative ease and is nearly equal to outdoor predicted sound levels. For the Project an indication of annoyance would be used as an indication of a LFN impact.

2.3.2 UK Department of Environment, Food, and Rural Affairs (DEFRA)

In February 2005 DEFRA published their *"Procedure for the assessment of low frequency noise disturbance"* which provides indoor LFN thresholds for disturbance. The DEFRA guidelines are based off of existing low frequency noise criteria from several countries (e.g., Sweden, Denmark, Netherlands, Germany, and Poland) and off of complaints of disturbance from LFN. DEFRA provides thresholds for 1/3-octave bands from 10 to 160 Hz for both non-steady and steady outdoor received sound levels in using the L_{eq} metric. The thresholds are generally 5 dB lower than the threshold of hearing to avoid disturbance. Recent studies have used these guidelines to establish outdoor equivalent sound levels for use in impact assessments (O'Neal 2011). Table 6 provides the outdoor non-stead and steady 1/3-octave LFN thresholds in dB L_{eq}. As indicated, there are no laws or regulations pertaining to LFN and IS from wind energy projects; however, the DEFRA guidelines provide thresholds from which an assessment of potential impact can be made.

Table 6. DEFRA Equivalent Outdoor dB L_{eq} 1/3-Octave Band Sound Pressure Thresholds

	1/3-Octave Band Center Frequency (Hz)												
Location	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Non-Steady Outdoor	94	89	86	78	68.5	61	56	51	51	49	47	45	43
Steady Outdoor	99	94	91	83	73.5	66	61	56	56	54	52	50	48

Source: DEFRA 2005, O'Neal 2011

3.0 EXISTING CONDITIONS

The acoustic analysis area for the Project includes Tax Map Keys (TMKs), or commonly referred to as parcels, located within 2 kilometers (km) or 1.2 miles of the Project. The mitigation areas for the Project are habitat areas for wildlife that may be affected from the Project. Because no operational or construction noise would result in these areas they are not included in the noise analysis area. Project components, such as WTGs and the substation, would be located on agriculturally zoned TMKs or HAR 11-46 Class C districts. The remaining TMKs within the noise analysis area are mostly agriculturally zoned; however, north and west of Project there are Class A (mostly residential) and Class B (mostly commercial) TMKs. Table 2 provides descriptions for each of the HAR 11-46 zoning Class Districts. The most restrictive land use from a noise compliance perspective with HAR 11-46 are the Class A TMKs located approximately 480 meters (1,575 feet) from the nearest Project WTG.

3.1 BASELINE SOUND SURVEY

A long term and short term baseline sound survey was completed in support of Project permitting, which provided a statistically relevant data set, covering the full range of wind speeds and future operational scenarios. Tetra Tech's extensive experience on wind energy projects sited in the U.S. indicates that this data set can typically be obtained over a 2-week monitoring period for long-term monitoring. The objective of the baseline sound survey is to establish the existing ambient sound environment of the Project Area. To fulfill this objective Tetra Tech completed the following steps:

1. A measurement program was developed and reviewed by Champlin including instrument selection and setup;
2. Measurement positions (MPs) for the sound survey were pre-selected to give a representative evaluation of baseline sound conditions over the entire Project Area. Landowner permissions were secured prior to the survey and locations were screened on the day of deployment to determine final measure positions;
3. Execution of baseline sound survey, which consisted of a two week monitoring period from April 22, 2014 to May 7, 2014 with data logging for the entire period at three long-term locations;
4. Long term 2-week measurements were supplemented by in-situ short-term (30-minute) measurements;
5. Analysis of baseline data, correlation with the Project's meteorological station representative of wind speed data at hub height of WTGs and presentation of typical values; and
6. Evaluation of masking of wind turbine noise by wind-induced background noise.

3.1.1 Instrumentation

Measurements were completed with either a Larson Davis 831 real-time sound level analyzer equipped with a PCB model 377B02 ½-inch precision condenser microphone or a Norsonic Model Nor140 precision sound analyzer with a Norsonic 1225 ½-inch precision condenser microphone. The Larson Davis 831 instrument has an operating range of 5 dB to 140 dB, and an overall frequency range of 8 to 20,000 Hz and the Norsonic Nor140 has the same operating range but also extends monitoring to lower frequencies with an overall frequency range of 1 to 20,000 Hz. Both devices meet or exceed all requirements set forth in the American National Standards Institute (ANSI) standards for Type 1 sound level meters for quality and accuracy (precision). All real-time sound level analyzers and instrumentation were calibrated per ANSI specifications to ensure the highest data accuracy possible. Laboratory calibrations occurred within the previous 12 month period with calibration documentation provided in Appendix A.

The sound level meters utilized are designed for service as a long-term environmental sound level data logger measuring the A-weighted sound level. Each unattended and weatherproof sound level monitoring position included a sound analyzer enclosed in a weatherproof case and equipped with a self-contained microphone tripod. The microphone and windscreen were tripod-mounted at an approximate height of 1.5 to 1.7 meters (4.9 to 5.6 feet) above grade away from effects of ground level rustling vegetation and fallen leaves. When sound measurements are attempted in the presence of elevated wind speeds, extraneous noise can be self-generated across the microphone. Air blowing over a microphone diaphragm creates a pressure differential and turbulence. All sound level analyzer microphones were protected from wind-induced extraneous noise effects by a 7 inch (180 millimeter) diameter foam windscreen made of specially prepared open-pored polyurethane. By using this microphone protection, the pressure gradient and turbulence is effectively moved further away from the microphone to ensure accurate collection of baseline data.

In addition, weather data were collected at or near the MPs using Vaisala portable weather transmitters, which operated over the full measurement period. Additional information on the Vaisala units is provided in Section 3.1.3.

3.1.2 Measurement Methodology

The baseline sound survey was conducted during a time of year where human activity is neither more nor less intensive than other times of year. Additionally, sounds produced by leaf and crop rustle as well as insect noise can elevate background sound levels and make correlation of background sound levels to wind speed difficult. Because there is little variation seasonally in vegetative cover, agricultural operations, and insect or other wildlife activity, baseline sound monitoring in the noise analysis area is considered to be typical of any time during the year. The lowest background sound levels typically occur on windless nights when the Project would not be operating. Thus, it is important that baseline sound level monitoring document the existing sound levels, day and night, for wind speeds in the range between WTG cut-in and the maximum rated power.

Using mapping and aerial photography of the Project Area, Tetra Tech selected three long term MP locations along the Project's site limit to be representative of noise sensitive receptors (NSRs) nearest to the Project. Tetra Tech attempted to locate monitoring equipment at the structures of the nearest NSR; however, when Champlin requested access from property owners or leases for deployment of monitoring equipment none were agreeable. As a result, Tetra Tech was restricted to placing long-term monitoring equipment at the Project site limit where Champlin had already obtained landowner permission and which was accessible to Tetra Tech. To supplement the long-term data collection short-term measurements were made from public rights-of-way, such as sidewalks, that did not require landowner access permission.

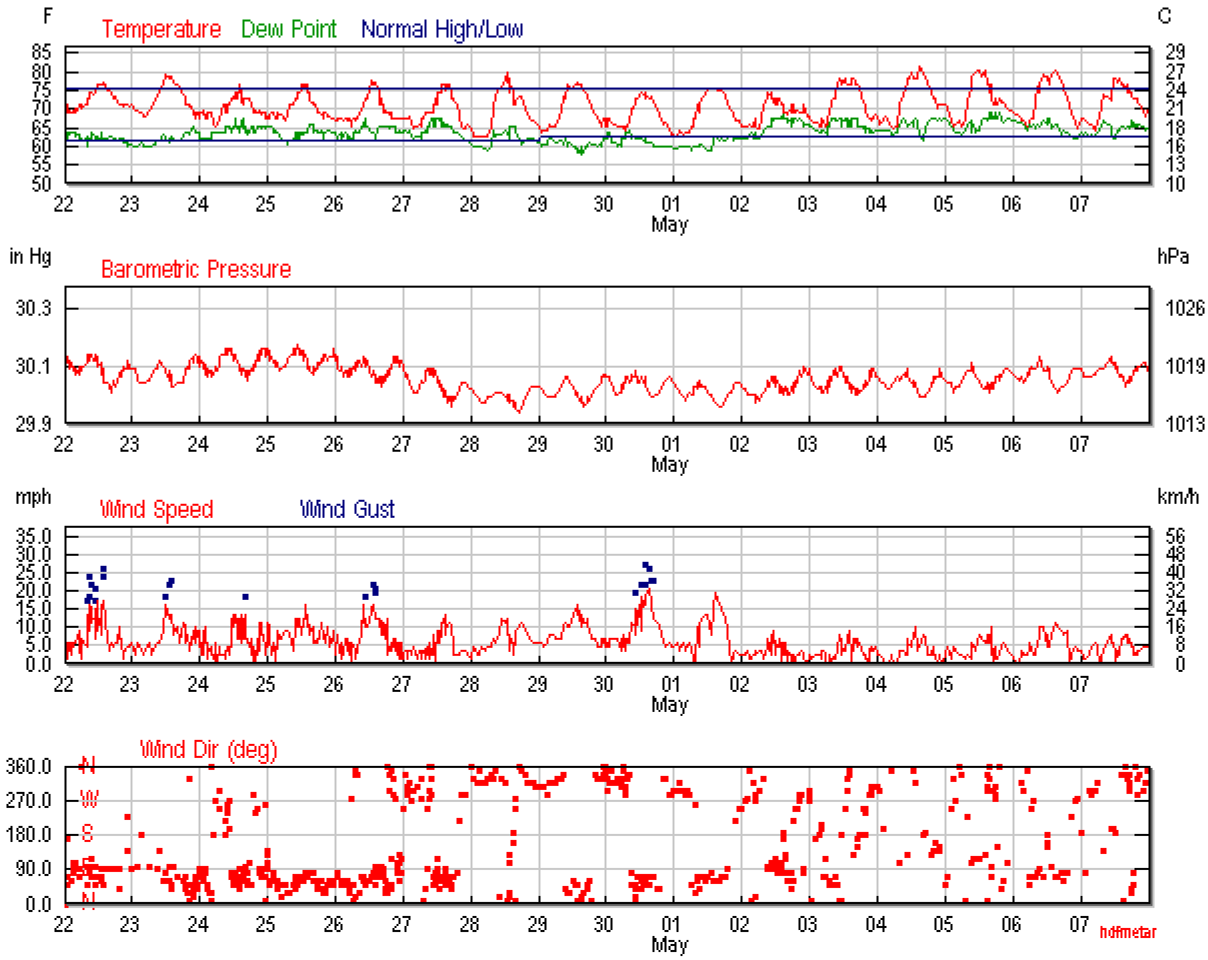
For each long-term measurement, a sound level meter was set up, calibrated, and run continuously in 1-hour and 10-minute intervals during daytime (7:00 am to 10:00 pm) and nighttime (10:00 p.m. to 7:00 a.m.) periods for the two week survey. The maximum observed calibration drift ranged from -0.1 dB to +0.1 dB, which is well within acceptable tolerances for long term baseline sound measurements. Each sound analyzer was programmed to measure and log broadband A-weighted sound pressure levels including a number of statistical parameters such as the average equivalent (L_{eq}), intrusive (L_{10}), median (L_{50}), and residual (L_{90}) sound levels. These data were logged for the duration of the baseline monitoring period to fully characterize the ambient acoustic environment of the Project Area. In addition, full (1/1) and third (1/3) octave band data were collected. All long-term monitoring stations were anchored in a manner that avoided interference from any large vertical reflective surfaces.

Short-term measurements were conducted with the Nor140 sound level meter at selected locations to provide additional information about the acoustical environment. The Nor140 is capable of monitoring to a lower frequency range (e.g., down to 1 Hz) which is useful for describing the LFN and IS content of the existing acoustic environment. Each short-term measurement was conducted for 30-minutes collected in 1-minute intervals, at least once during midday (10:00 a.m. to 3:00 p.m.) to avoid peak hours of traffic noise on area roadways and/or during nighttime hours (12:00 a.m. to 4:00 a.m.), depending on access and safety. The same metrics and octave band data were collected during the short-term measurements as that for the long-term measurements.

Following the completion of the measurement period, all measured data were downloaded and analyzed. Long-term monitoring data were correlated with hub height (approximately 80 meters) wind speed data using a standardized statistical regression analysis methodology. In addition, daytime and nighttime observations were documented during equipment deployment, retrieval, and short-term measurements to identify sound sources with the nighttime period of particular interest as this is a time period of heightened sensitivity to noise (i.e., sleep interruption).

3.1.3 Meteorological Conditions

Champlin provided Tetra Tech wind speed and direction data from their on-site meteorological (MET) towers for the period of the baseline sound survey, given in 10-minute increments. In addition weather data were collected at the long-term MPs using the Vaisala units. The Vaisala unit monitors wind speed and direction via its ultrasonic anemometer, and also measures barometric pressure, temperature and humidity, total rainfall, intensity, and duration of rainfall. The Vaisala unit is also able to distinguish between precipitation type such as rain, hail, and snow. When required, data gaps from the Champlin's MET data were supplemented with the data from the Vaisala units. Figure 1 shows general weather conditions during the baseline sound survey in the vicinity of the Project Area.



Source: Weather Underground, 2014

Figure 1. Baseline Sound Survey Weather Conditions

3.1.4 Sound Survey Results

The three long-term sound monitoring stations were deployed at the Project site limit at locations closest to the nearest NSRs. Table 7 summarizes the UTM coordinates, distance to the nearest proposed WTG, and sound level meter's serial number (S/N) used to collect data for each long-term MP. Figure 2 provides a map of the MPs and acoustic analysis area HAR 11-46 zoning classes.

Table 7. Long-Term Monitoring Position Location Summary

Monitoring Position	UTM Coordinates (NAD83 UTM Zone 14 N)		Distance to Nearest Project WTG (m)	Distance to Nearest Existing Kahuku WTG (m)	SLM Serial Number
	Easting (m)	Northing (m)			
LT-1	606,540.04	2,396,927.75	68.1	326.7	1350 & 14027964
LT-2	607,962.82	2,396,713.27	495.8	1,674.2	3140
LT-3	608,537.47	2,396,811.61	220.6	2,197.0	1403045

Table 8 provides the summary of short-term monitoring locations conducted from public rights-of-way near selected NSRs in the acoustic analysis area.

Table 8. Short-Term Monitoring Position Location Summary

Monitoring Position	UTM Coordinates (NAD83 UTM Zone 14 N)		Distance to the Nearest WTG (m)	Distance to Nearest Existing Kahuku WTG (m)	Serial Number
	Easting (m)	Northing (m)			
ST-1	607,030.73	2,397,241.57	640.6	670.6	1403045
ST-2	607,875.34	2,396,999.59	783.1	1,517.3	1403045
ST-3	608,444.81	2,397,077.41	496.2	2,017.1	1403045
ST-4	609,940.67	2,395,748.07	1,270.4	3,863.1	1403045
ST-5	606,075.81	2,399,058.66	2,235.9	474.6	14027964 & 1403045
ST-6	606,962.96	2,396,334.02	349.2	1,055.4	14027964

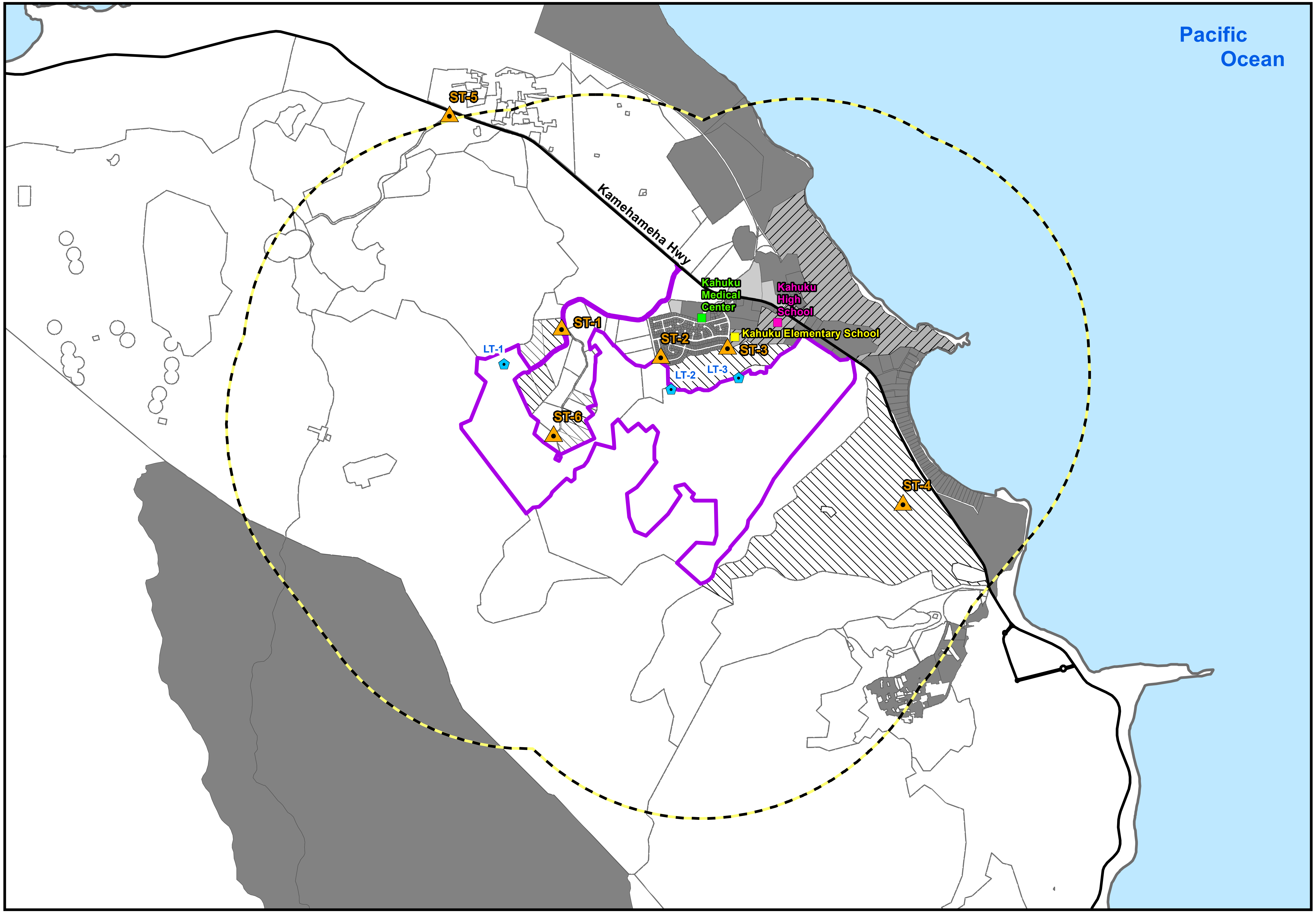


Figure 2

Na Pua Makani Wind Project

Acoustic Monitoring Positions and HAR 11-46 Zoning Classes

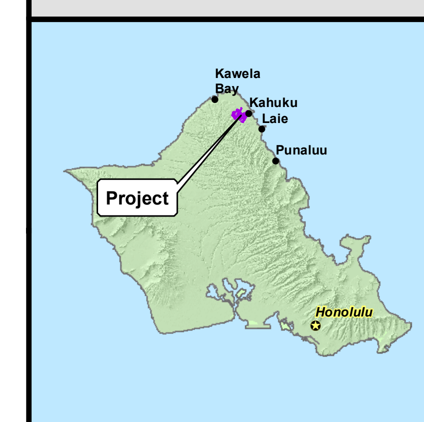
Oahu, HI

Mach 2015

- Wind Farm Site Boundary
- Acoustic Study Area
- Local Road
- Short Term Monitoring Positions
- Sound Monitoring Position
- Kahuku Elementary School
- Kahuku High School
- Kahuku Medical Center

HAR Zone

- Class A (45 dBA Limit)
- Class A (55 dBA Limit) - Day Use Only
- Class B (50 dBA Limit)
- Class C (70 dBA Limit) - Has Residence
- Class C (70 dBA Limit) - No Residence or Project TMK



1:32,000 WGS84 UTM 4

0 0.5 1 2 3 4 5 Miles

Data Sources Champlin: project facilities / ESRI: roads / Hawaii Statewide GIS Program: zoning classification

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The baseline sound survey measurement data incorporate all sounds at the MP including contributions from road traffic, sounds of nature, existing industrial facilities, and other human related activities. Long-term monitoring data points below the cut-in wind speed of three meters per second (m/s) for the proposed WTGs and any adversely affected data (external extraneous noise sources) were excluded from the analysis. The refined dataset was evaluated using a regression analysis for each MP as well as all MPs cumulatively grouped for the entire Project Area. Short-term measurements were all conducted during wind speed conditions where the Project would be in operation according to the Project's MET tower with wind speeds ranging from 6 m/s to 11 m/s.

The acoustic monitoring data collected at each MP were matched to Champlin's MET station which monitors wind speeds at 50 meters and that Champlin scaled up to 80 meters, roughly the hub height of the WTGs under consideration. Additionally, each MP's respective Vaisala unit was also matched to the acoustic monitoring data. These two wind speed datasets accurately characterize wind speed conditions at each MP. The 10-minute L_{eq} sound levels were correlated to wind speed (m/s) at an 80 meter (262 feet) hub height with a regression analysis and the best fit correlation coefficient using a second order polynomial equation. The 10-minute L_{eq} sound levels were divided into daytime (7:00 am to 10:00 pm) and nighttime (10:00 pm to 7:00 am) periods to show diurnal variation at each MP. The following subsections present results by MP. Table 9 provides the broadband dBA L_{eq} tabular results of the baseline monitoring survey at integer wind speeds, which is consistent with the limits prescribed in HAR 11-46, which are also given in dBA L_{eq}. The subsections that follow provide 1/3-octave band data results in dB L_{eq} for use with the LFN DEFRA limits.

Table 9. Baseline Monitoring Results at Integer Wind Speeds

Monitoring Position*	Time of Day	dBA L_{eq} by Wind Speed (m/s)								
		Calm	3	4	5	6	7	8	9	10+
LT-1	7AM-10PM	40	45	47	50	50	49	51	52	55
	10PM-7AM	N/A***	43	43	44	47	48	49	50	52
LT-2	7AM-10PM	46	41	45	50	47	46	47	46	48
	10PM-7AM	47	51	42	46	48	46	44	47	45
LT-3	7AM-10PM	42	45	45	44	46	45	45	45	49
	10PM-7AM	44	44	43	40	42	43	43	45	45

Note: *short-term measurements were conducted for 30-minute periods which do not include all operational wind speed conditions. **Vehicle pass-by events removed. ***No "calm" time periods during monitoring.

Monitoring Position: LT-1

LT-1 was located within the Project site along the northwest Project site limits 68m from the Project's proposed WTG #1 and 327m from the nearest existing Kahuku Wind Farm WTG. Deployment occurred on April 23, 2012 at approximately 10:00 AM during sunny and warm (77°F) weather conditions. The elevation at LT-1 is approximately 20 m above sea level (ASL). Noise sources observed during deployment included the existing Kahuku Wind Farm, wind interacting with vegetation, helicopter and fixed-wing aircraft flyovers, and nearby agricultural activities involving small combustion engine equipment. LT-1 included the two sound level meters, one LD831 and one Norsonic 140 for redundancy. Redundancy was desirable at this location because Tetra Tech wanted to collect sound data generated from the existing Kahuku Wind Farm. During the course of the survey the Norsonic 140 experienced technical issues; however, these issues did not prevent collection of a statistically significant dataset that is appropriate for establishing baseline conditions. Figure 3 presents a photograph of the two sound level meters deployed relative to the existing Kahuku Wind Farm from the viewpoint of the Project's site limit. Figure 4 provides the time history and Figure 5 provides the regression analyses of ambient sound levels during daytime and nighttime monitoring periods. Figure 6 provides the 1/3-octave band spectral data at cut-in (3 m/s) and maximum rotational (8 m/s) wind speeds relative to the threshold of human hearing. None of the infrasound levels monitored were above the threshold of human hearing. Table 10 provides the 1/3-octave band monitoring results spanning the frequencies from 4Hz to 5000 Hz.

Figure 3. Photo of LT-1

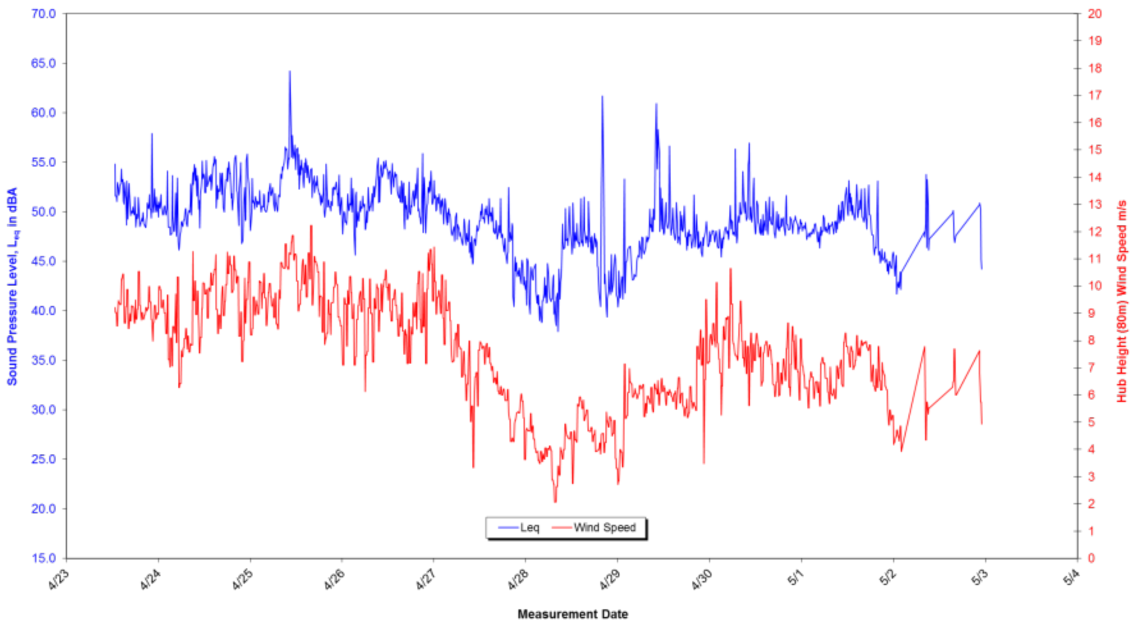

Figure 4. LT-1 Time History Plot

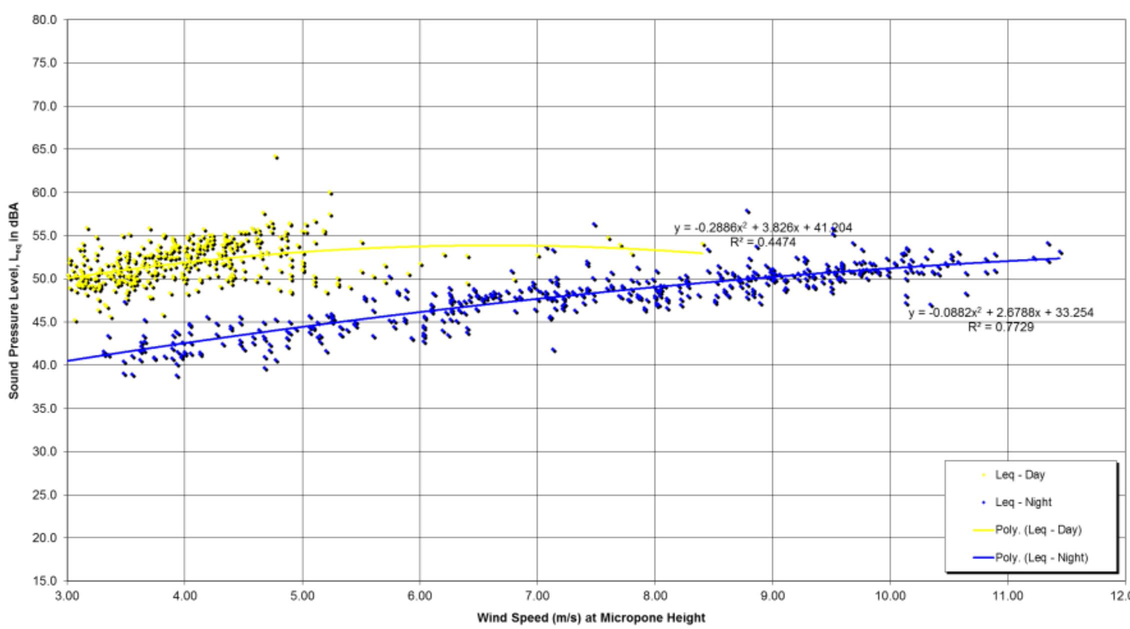

Figure 5. LT-1 Regression Analysis

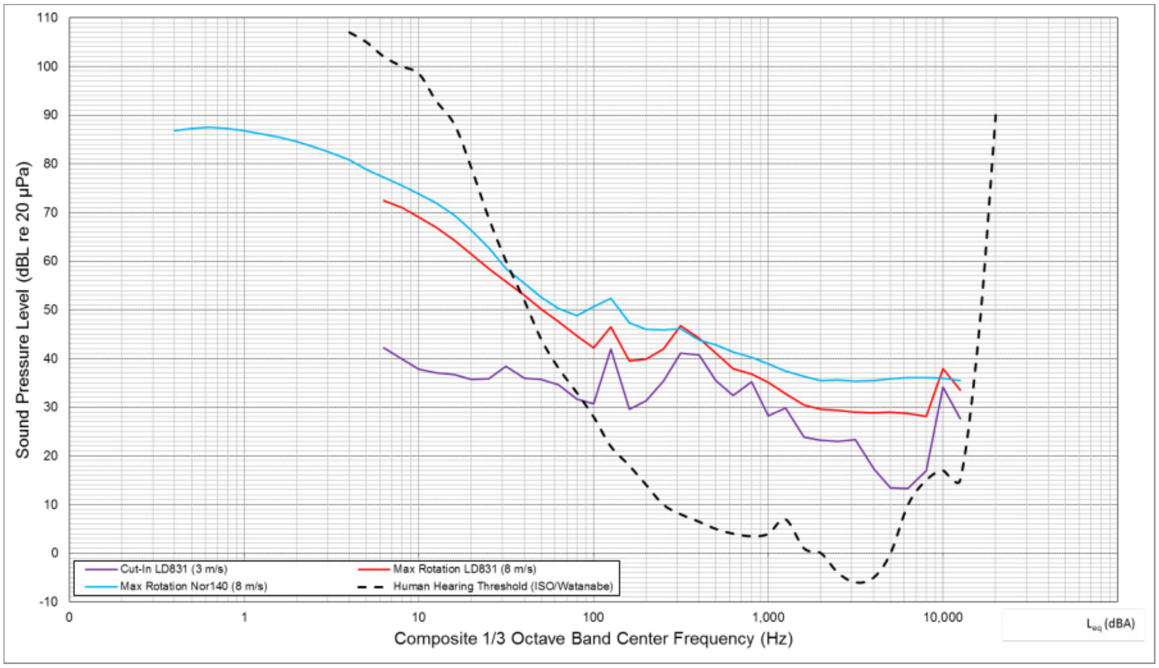

Figure 6. LT-1 1/3-Octave Band Spectral Plot

Table 10. LT-1 1/3-Octave Band Baseline Monitoring Results at Integer Wind Speeds

Frequency Range	1/3-Octave Band (Hz)	dBA L_{eq} by Wind Speed (m/s)							
		3	4	5	6	7	8	9	10
Infrasound	4.0*	-	-	-	74	77	81	82	85
	5.0*	-	-	-	72	75	79	80	83
	6.3	60	60	64	69	71	73	74	75
	8.0	58	58	62	67	70	72	73	74
	10.0	55	56	59	65	68	70	71	72
	12.5	52	53	56	62	66	68	69	71
	16.0	49	50	53	59	63	65	67	69
Low Frequencies	20.0	50	51	52	57	60	63	65	66
	25.0	49	47	48	53	57	60	62	64
	31.5	44	45	48	51	54	57	59	61
	40.0	43	43	45	49	51	54	57	59
	50.0	44	45	45	47	49	52	54	56
	63.0	42	41	42	45	46	49	51	53
	80.0	43	40	40	44	44	47	48	50
	100	41	39	39	43	42	44	46	48
	125	44	45	46	47	47	48	48	48
	160	39	39	38	43	40	42	43	44
	200	37	38	37	43	40	42	42	42
Selected Mid Frequencies	250	38	40	41	42	42	43	44	44
	315	41	43	45	47	47	46	47	47
	400	41	42	43	45	45	44	44	44
	500	38	39	40	42	42	42	41	41
	630	34	35	37	40	38	39	39	39
	800	36	37	37	40	38	38	38	38
	1000	31	32	33	37	36	36	37	37
	1250	30	31	32	35	34	35	35	35
	1600	26	28	29	33	32	32	33	34
	2000	27	28	28	32	31	32	32	33
	2500	28	28	27	31	31	32	32	34

Table 10. LT-1 1/3-Octave Band Baseline Monitoring Results at Integer Wind Speeds

Frequency Range	1/3-Octave Band (Hz)	dBA L_{eq} by Wind Speed (m/s)							
		3	4	5	6	7	8	9	10
	3150	28	27	26	30	31	32	32	34
	4000	22	24	23	29	30	32	33	34
	5000	20	23	23	29	30	32	33	35

Note: *Data monitored using Norsonic 140. All other data monitored with Larson Davis 831

Monitoring Position: LT-2

LT-2 was located within the Project site along the north central Project site limits 496m from the Project's proposed WTG #6 and 1,674m from the nearest existing Kahuku Wind Farm WTG. The location of LT-2 was chosen to represent a cluster of single-family housing 204m north. Deployment occurred on April 23, 2012 at approximately 11:10 AM during sunny and warm (80°F) weather conditions. The elevation at LT-2 is approximately 5m ASL. Sound sources observed during deployment included the light wind interacting with vegetation, distant agricultural equipment, helicopter and fixed-wing aircraft flyovers, and periodic wildlife including insects and stray dogs. The area is relatively sheltered from wind being surrounded by a tree line separating it from other agricultural lands to the south and the residential area to the north. The location is also slightly lower in elevation than the houses in the nearby development which are 34m ASL. Monitoring at LT-2 was accomplished using a LD831 which operated for the entire two week monitoring period providing a statistically significant dataset appropriate for establishing baseline conditions. Figure 7 presents a photograph of the two sound level meters deployed taken in the direction of the residential development. Figure 8 provides the time history and Figure 9 provides the regression analyses of ambient sound levels during daytime and nighttime monitoring periods. As the time history and regression analysis shows there is little variation in sound level when hub height wind speeds are elevated which confirms that the area is relatively sheltered from the wind. Short-term monitoring in the neighborhood was necessary to ascertain wind effects at the slightly higher elevation which was accomplished via ST-2. Figure 10 provides the 1/3-octave band spectral data at cut-in (3 m/s) and maximum rotational (8 m/s) wind speeds relative to the threshold of human hearing. None of the infrasound levels monitored were above the threshold of human hearing. Table 11 provides the 1/3-octave band monitoring results spanning the frequencies from 6.3Hz to 5000 Hz.

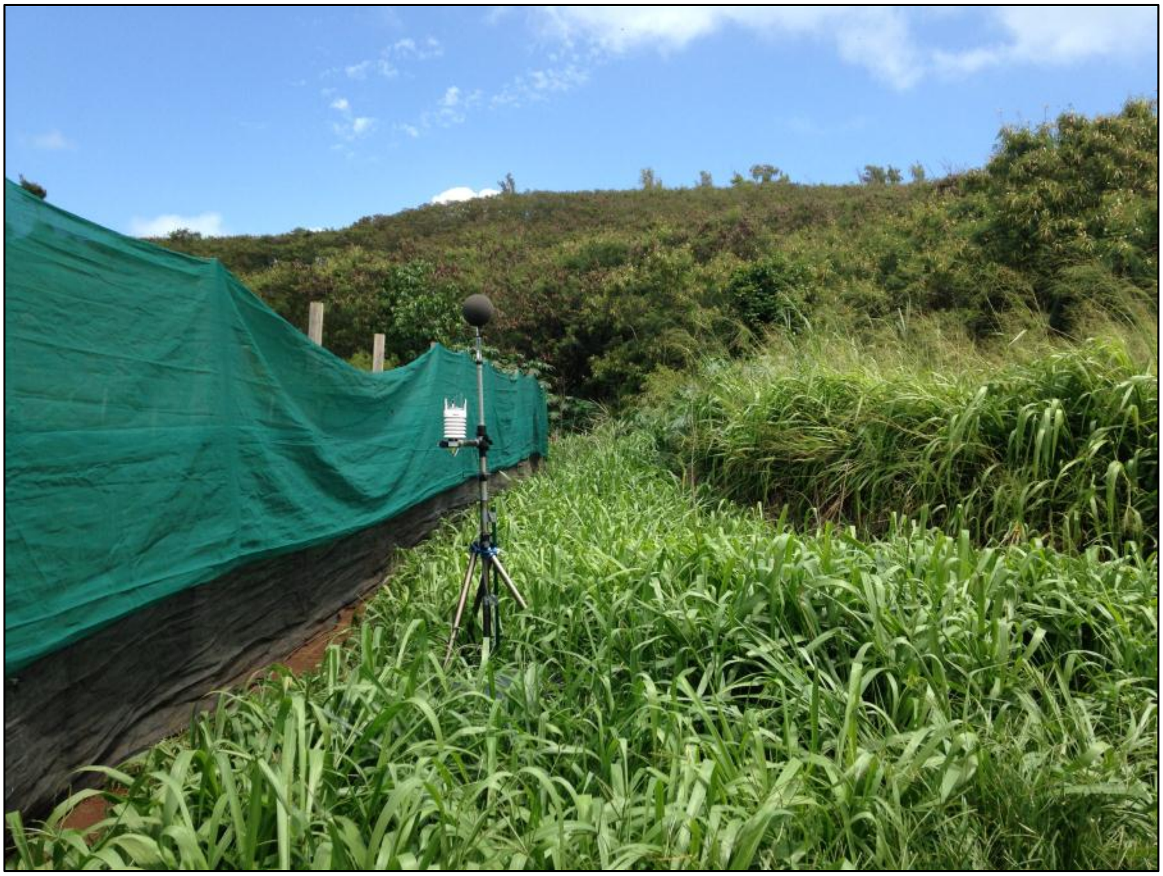

Figure 7. Photo of LT-2

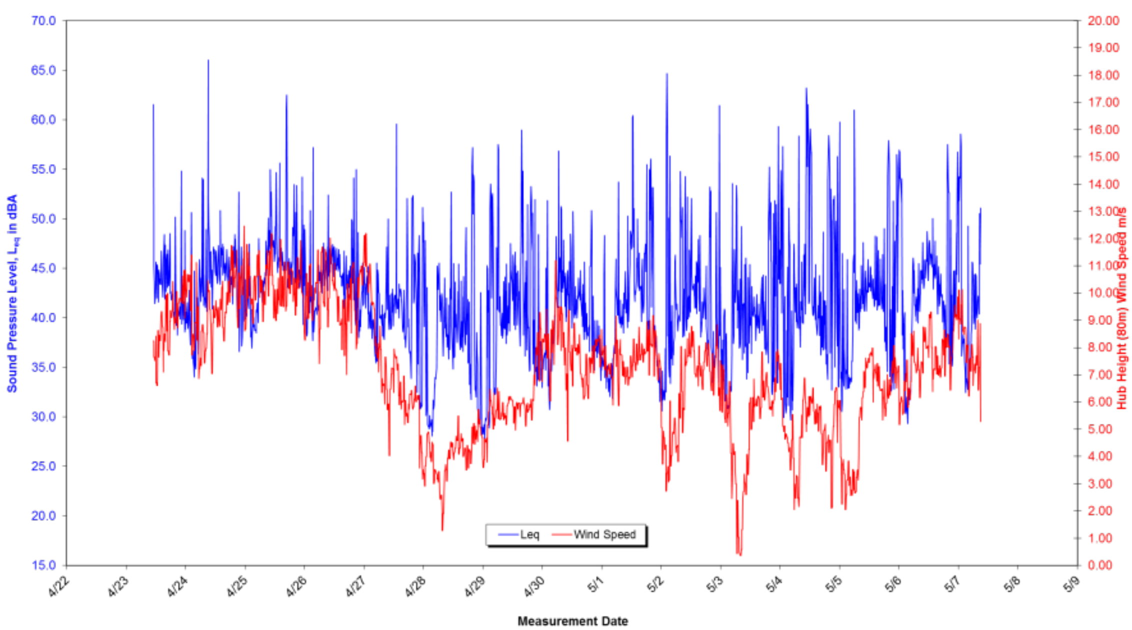

Figure 8. LT-2 Time History Plot

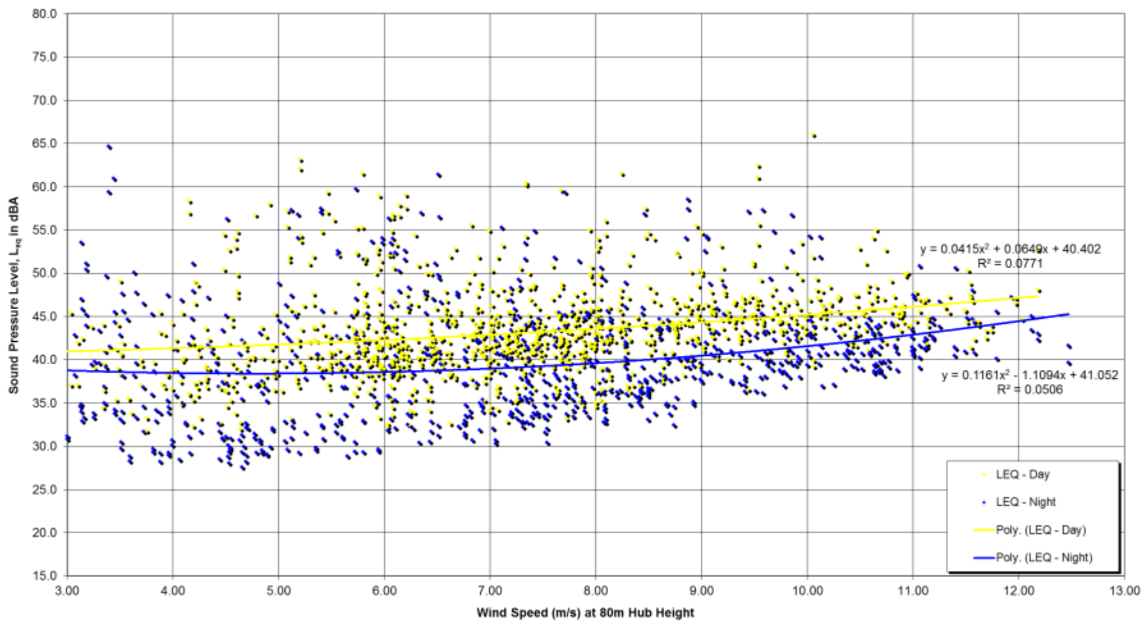

Figure 9. LT-2 Regression Analysis

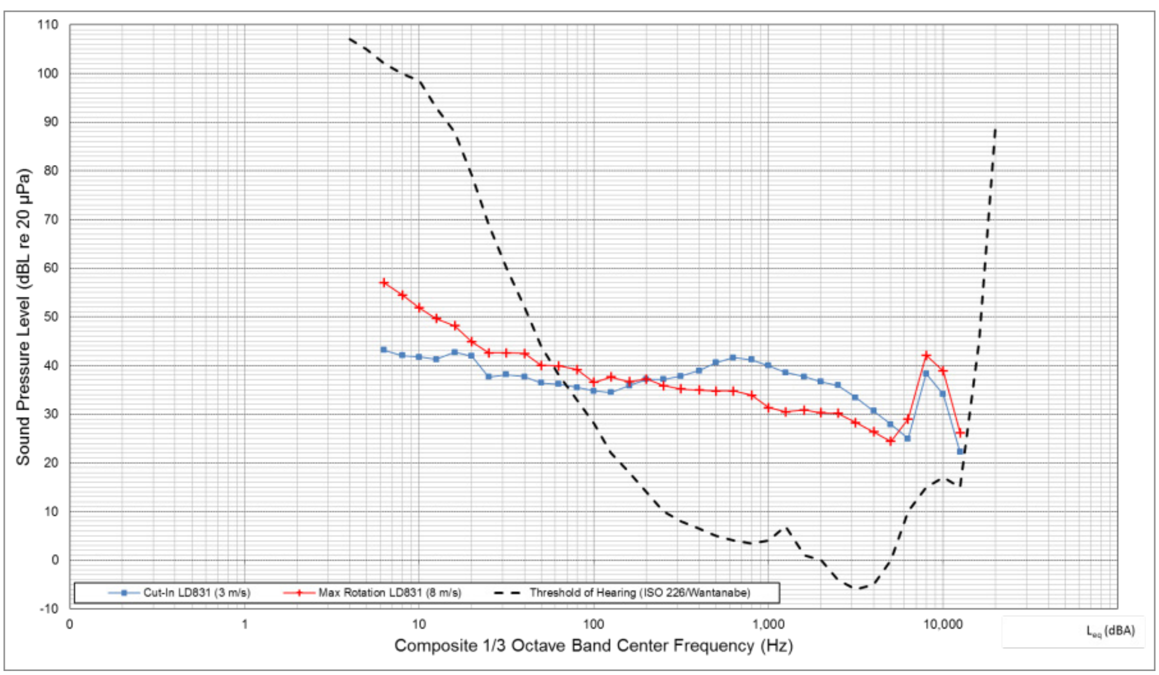

Figure 10. LT-2 1/3-Octave Band Spectral Plot

Table 11. LT-2 1/3-Octave Band Baseline Monitoring Results at Integer Wind Speeds

Frequency Range	1/3-Octave Band (Hz)	dBA L_{eq} by Wind Speed (m/s)							
		3	4	5	6	7	8	9	10
Infrasound	4.0*	-	-	-	-	-	-	-	-
	5.0*	-	-	-	-	-	-	-	-
	6.3	43	47	50	54	56	57	59	60
	8.0	42	45	48	51	54	54	57	58
	10.0	42	43	46	49	51	52	54	55
	12.5	41	43	44	47	49	50	52	52
	16.0	43	46	45	47	48	48	50	51
Low Frequencies	20.0	42	39	40	43	44	45	46	48
	25.0	38	37	39	42	43	43	44	45
	31.5	38	40	41	44	44	43	44	45
	40.0	38	36	39	44	46	42	45	45
	50.0	36	36	39	43	43	40	41	43
	63.0	36	35	41	44	43	40	40	46
	80.0	36	32	43	44	42	39	41	47
	100	35	31	39	41	40	37	38	42
	125	34	32	35	43	42	38	38	40
	160	36	32	36	37	36	37	38	39
	200	37	32	37	37	37	37	38	40
Selected Mid Frequencies	250	37	32	38	37	36	36	37	38
	315	38	31	37	35	35	35	36	37
	400	39	29	37	36	35	35	35	37
	500	41	30	37	36	36	35	36	36
	630	42	30	37	36	35	35	36	36
	800	41	29	37	36	34	34	34	35
	1000	40	27	35	34	32	31	32	36
	1250	39	27	33	32	30	30	31	33
	1600	38	30	34	31	30	31	32	37
	2000	37	29	34	32	30	30	33	35
	2500	36	29	37	33	30	30	34	37
	3150	33	24	34	31	28	28	30	35
	4000	31	22	31	28	26	26	28	32
	5000	28	19	29	26	24	24	28	27

Note: *The LD831 has a functional monitoring limit of 6.3Hz lower frequencies were not monitored at LT-2.

Monitoring Position: LT-3

LT-3 was located within the Project site along the northeastern Project site limits 221m from the Project's proposed WTG #10 and 2,197m from the nearest existing Kahuku Wind Farm WTG. The location of LT-3 was chosen to represent the Kahuku Elementary and High Schools as well as residential areas adjacent to them which are approximately 230m north. Deployment occurred on April 23, 2012 at approximately 11:40 AM during sunny and warm (80°F) weather conditions. The elevation at LT-3 is approximately two meters ASL. Sound sources observed during deployment included the light wind interacting with vegetation, distant agricultural equipment, helicopter and fixed-wing aircraft flyovers, and periodic wildlife including insects. Like LT-2 the area is relatively sheltered from wind being surrounded by a tree line separating it from other agricultural lands to the south and the schools/residential area to the north. The location is also slightly lower in elevation than the schools/residential area which are five meters ASL. Monitoring at LT-3 was accomplished using a Norsonic 140 which operated for the entire two week monitoring period providing a statistically significant dataset appropriate for establishing baseline conditions. Figure 11 presents a photograph of the two sound level meters deployed taken in the direction of the residential development. Figure 12 provides the time history and Figure 13 provides the regression analyses of ambient sound levels during daytime and nighttime monitoring periods. As the time history and regression analysis shows there is little variation in sound level when hub height wind speeds are elevated which confirms that the area is relatively sheltered from the wind. Short-term monitoring in the neighborhood was necessary to ascertain wind effects at the slightly higher elevation which was accomplished via ST-3. Figure 14 provides the 1/3-octave band spectral data at cut-in (3 m/s) and maximum rotational (8 m/s) wind speeds relative to the threshold of human hearing. None of the infrasound levels monitored were above the threshold of human hearing. Table 12 provides the 1/3-octave band monitoring results spanning the frequencies from 6.3Hz to 5000 Hz.

Figure 11. Photo of LT-3

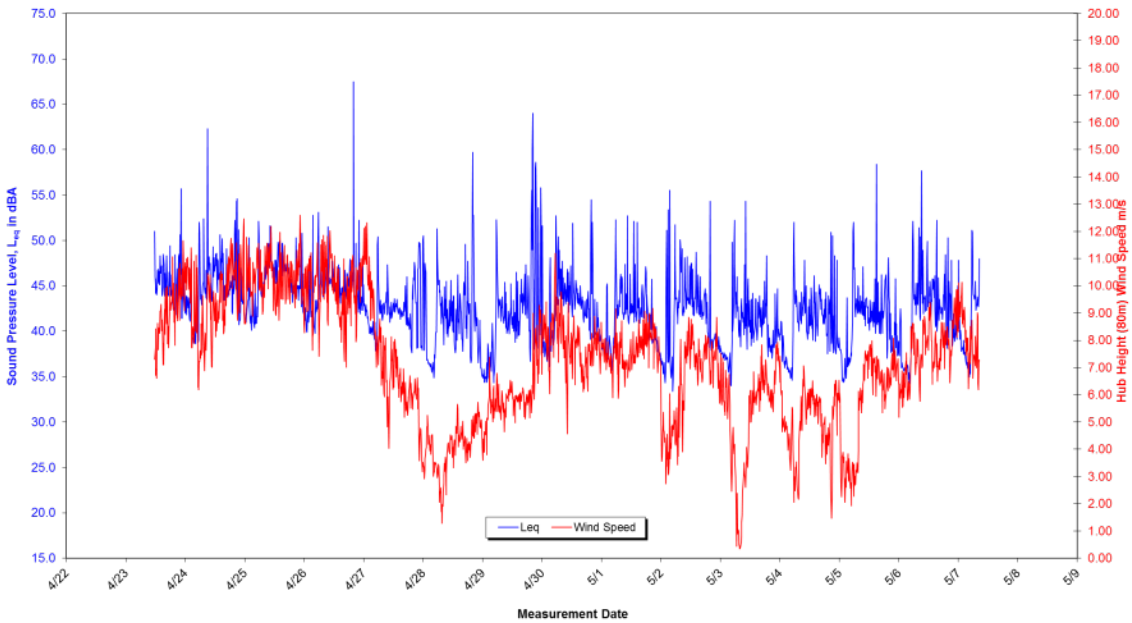

Figure 12. LT-3 Time History Plot

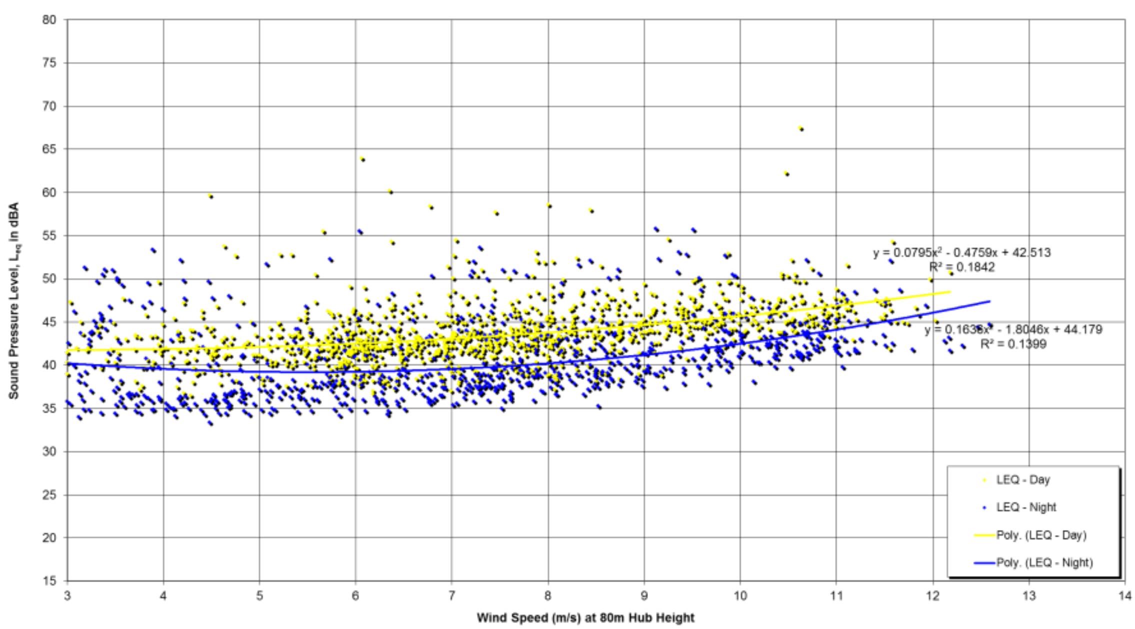

Figure 13. LT-3 Regression Analysis

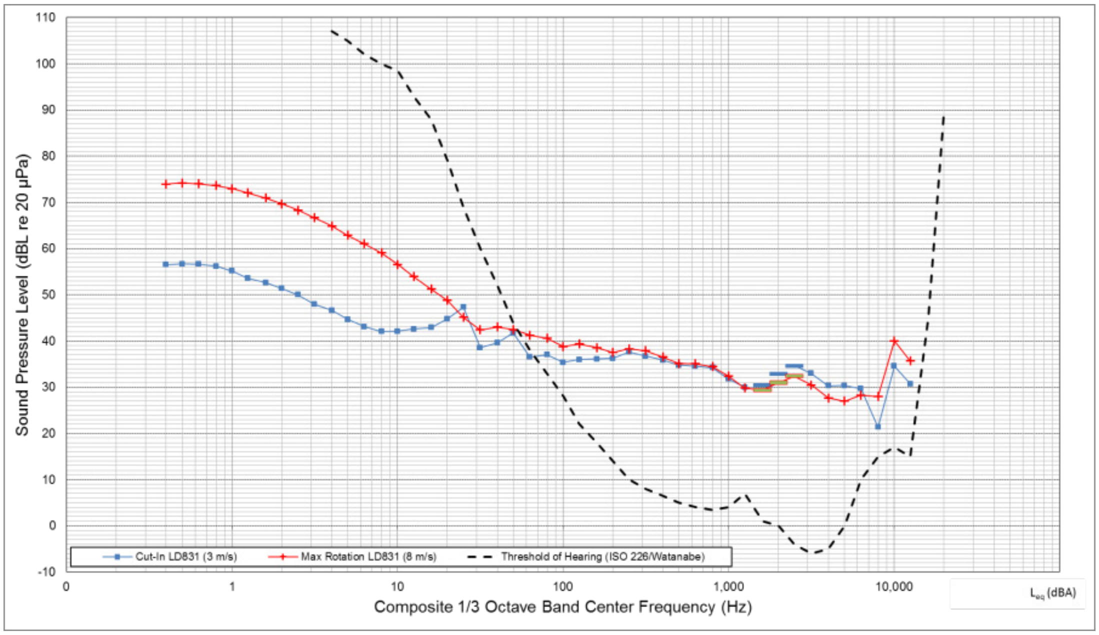

Figure 14. LT-3 1/3-Octave Band Spectral Plot

Table 12. LT-3 1/3-Octave Band Baseline Monitoring Results at Integer Wind Speeds

Frequency Range	1/3-Octave Band (Hz)	dBA L_{eq} by Wind Speed (m/s)							
		3	4	5	6	7	8	9	10
Infrasound	4.0	47	53	56	60	62	65	69	71
	5.0	45	51	54	58	60	63	67	69
	6.3	43	49	52	56	58	61	65	67
	8.0	42	47	50	54	56	59	64	66
	10.0	42	45	47	51	53	57	61	64
	12.5	43	43	45	48	51	54	59	61
	16.0	43	43	44	47	48	51	56	58
Low Frequencies	20.0	45	43	43	46	47	49	53	55
	25.0	47	39	39	41	46	45	49	52
	31.5	39	38	39	40	42	42	46	48
	40.0	40	39	39	41	42	43	45	46
	50.0	42	38	36	39	42	42	44	44
	63.0	37	37	38	37	44	41	43	44
	80.0	37	35	37	38	43	41	42	42
	100	35	34	35	35	41	39	40	41
	125	36	33	33	35	40	39	40	41
	160	36	34	34	36	38	39	40	41
	200	36	33	33	35	38	38	39	41
Selected Mid Frequencies	250	38	34	34	36	38	38	40	42
	315	37	34	34	36	38	38	39	40
	400	36	33	33	35	37	37	37	39
	500	35	32	32	33	36	35	36	38
	630	35	32	31	33	36	35	36	37
	800	34	32	30	32	35	34	35	37
	1000	32	30	28	30	32	32	34	36
	1250	30	28	26	28	30	30	32	34
	1600	30	28	27	28	29	29	31	32
	2000	33	31	29	30	31	31	32	32
	2500	35	33	31	32	32	32	33	35
	3150	33	31	29	31	31	30	31	33
	4000	30	28	25	26	28	28	29	33
	5000	30	28	25	24	27	27	29	30

Monitoring Position: ST-1

The ST-1 measurement was conducted on April 23, 2014 from 5:00PM to 5:30PM along public ROW near leased Hawaii Department of Agriculture (DOA) parcels that have single-family residences. The measurement was conducted to capture monitoring data at these residences where long-term equipment deployment was not allowed. Data collected at ST-1 are meant to provide additional information to characterize the DOA parcels that are located closest to the existing Kahuku Wind Farm. A daytime measurement was conducted at ST-1 with observed sound sources including the existing WTGs at the Kahuku Wind Farm, wind interacting with vegetation, periodic aircraft flyovers, and periodic small combustion engine agricultural equipment. Traffic noise along the Kamehameha Highway was not audible during the measurement or was masked by other sounds including the existing WTGs. Figure 15 provides the 1/3-octave band spectral data for the monitoring period which included hub height wind speeds of 10 m/s. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

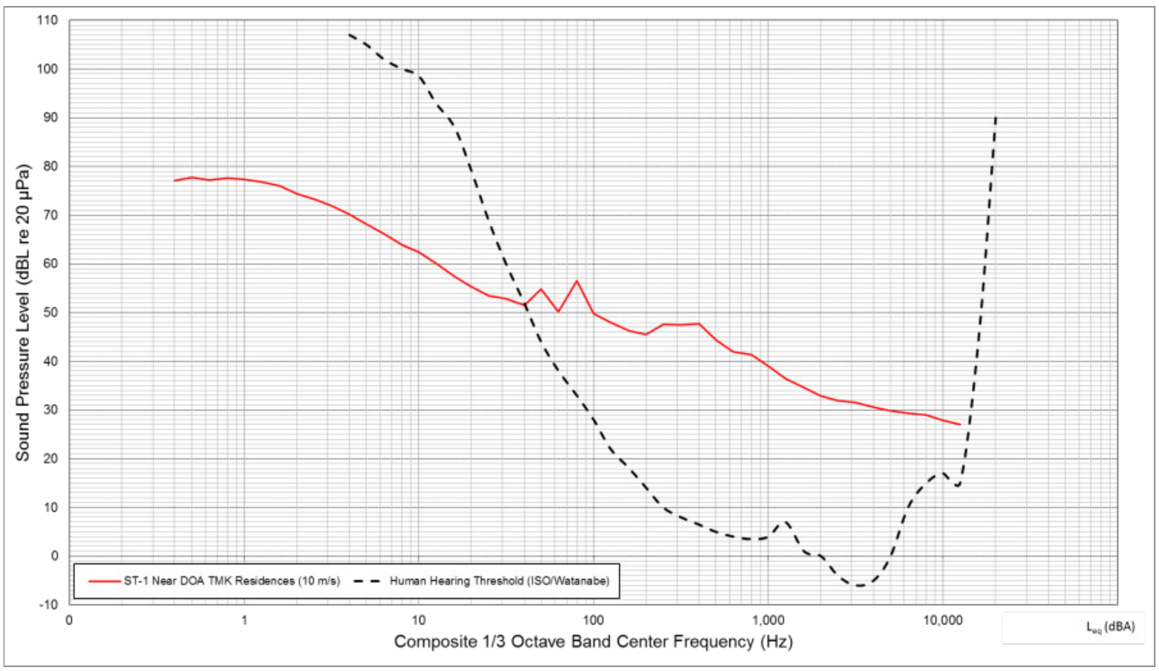

Figure 15. ST-1 1/3-Octave Band Spectral Plot

Monitoring Position: ST-2

The ST-2 measurement was conducted on April 22, 2014 from 2:05PM to 2:35PM along public ROW in the southwest portion of a relatively densely populated housing development referred to as the "Mauka Village". The measurement was conducted to capture monitoring data at these residences where long-term equipment deployment was not allowed. ST-2 is meant to provide additional support data to characterize ambient conditions at these residences which are also represented by LT-2. A daytime measurement was conducted at ST-2 with observed sound sources including the roadway traffic, wind interacting with structures, dogs periodically barking during set up of the meter, people conversing, and periodic helicopter and fixed-wing aircraft flyovers. Figure 16 provides the 1/3-octave band spectral data for the monitoring period which included hub height wind speeds of 10 m/s. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

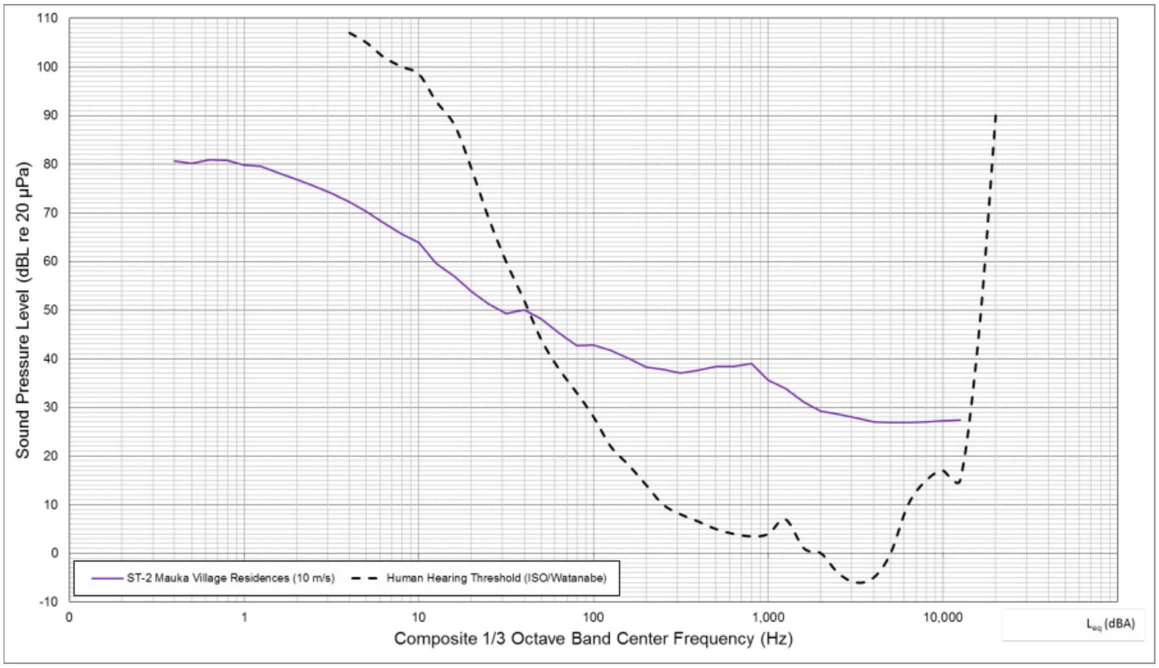

Figure 16. ST-2 1/3-Octave Band Spectral Plot

Monitoring Position: ST-3

Measurements at ST-3 were conducted on April 22, 2014 along public ROW adjacent to the northwest fence line of the Kahuku Elementary School and are representative of the acoustic environment of the schools and residences nearby which are also included in the “Mauka Village”. The measurement was conducted to capture monitoring data where long-term equipment deployment was not allowed. ST-3 is meant to provide additional support data to characterize ambient conditions at the schools and residences which are also represented by LT-3. A daytime measurement was conducted from 2:45PM to 3:15PM and a nighttime measurement was conducted from 11:02PM to 11:32PM. Observed daytime sound sources included local roadway traffic, wind interacting with structures and vegetation, distant yard maintenance, people conversing, and periodic helicopter and fixed-wing aircraft flyovers. Nighttime observations included periodic traffic, people conversing at nearby residences, wind interacting with structures and vegetation, and minimal insect noise. Hub height wind speeds during the daytime measurement were 11 m/s and were 9 m/s at night. Figure 17 provides the 1/3-octave band spectral data for the daytime and nighttime monitoring periods. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

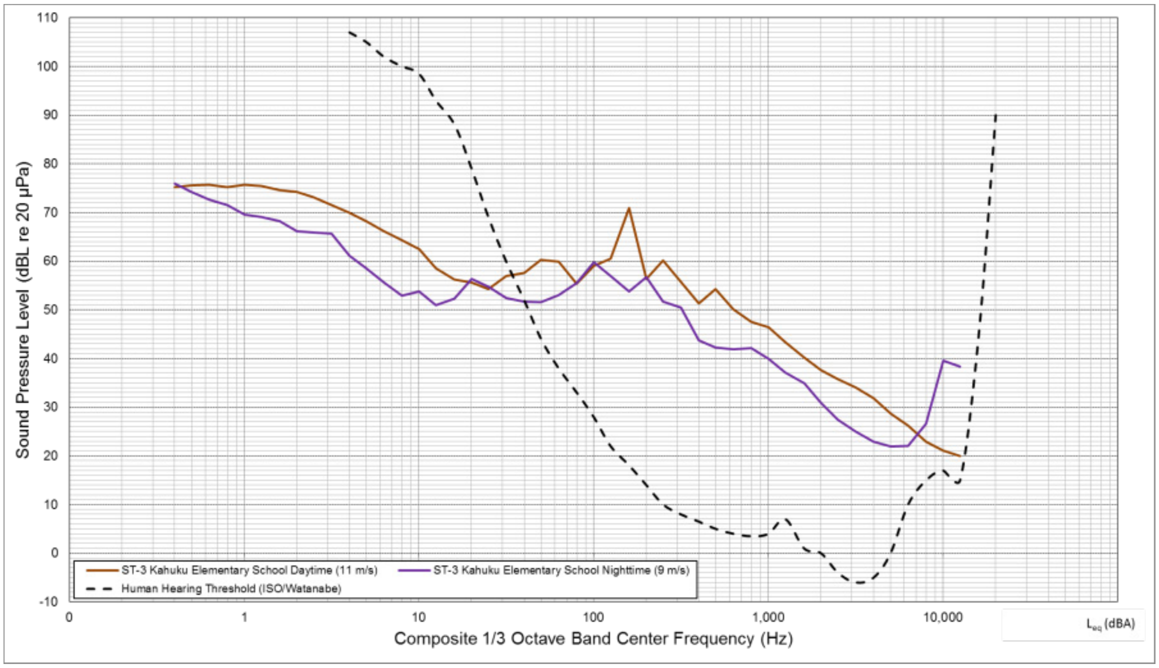

Figure 17. ST-3 1/3-Octave Band Spectral Plot

Monitoring Position: ST-4

Measurements at ST-4 were conducted on April 22, 2014 along limited public ROW near the Gunstock Ranch and are representative of the ranch and nearby rural residences located approximately one kilometer from the Project. The measurement was conducted to capture monitoring data where long-term equipment deployment was not allowed and to verify that long-term monitors at LT-2 and LT-3 are sufficiently representative of this area as well. A daytime measurement was conducted from 3:24PM to 4:03PM and a nighttime measurement was conducted from 10:26PM to 10:56PM. Because the landowners were in the process of locking the limited public access dirt road when field engineers arrived to conduct the nighttime measurement an alternate location was utilized at the entrance off of the Kamehameha Highway. Observed daytime sound sources included periodic local roadway traffic, traffic on the Kamehameha Highway, wind interacting vegetation, distant yard maintenance, people conversing, and periodic helicopter and fixed-wing aircraft flyovers. Nighttime observations included limited traffic on the Kamehameha Highway, wind interacting vegetation, and minimal insect noise. Hub height wind speeds during the daytime measurement were 11 m/s and were 9 m/s at night. Figure 18 provides the 1/3-octave band spectral data for the daytime and nighttime monitoring periods. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

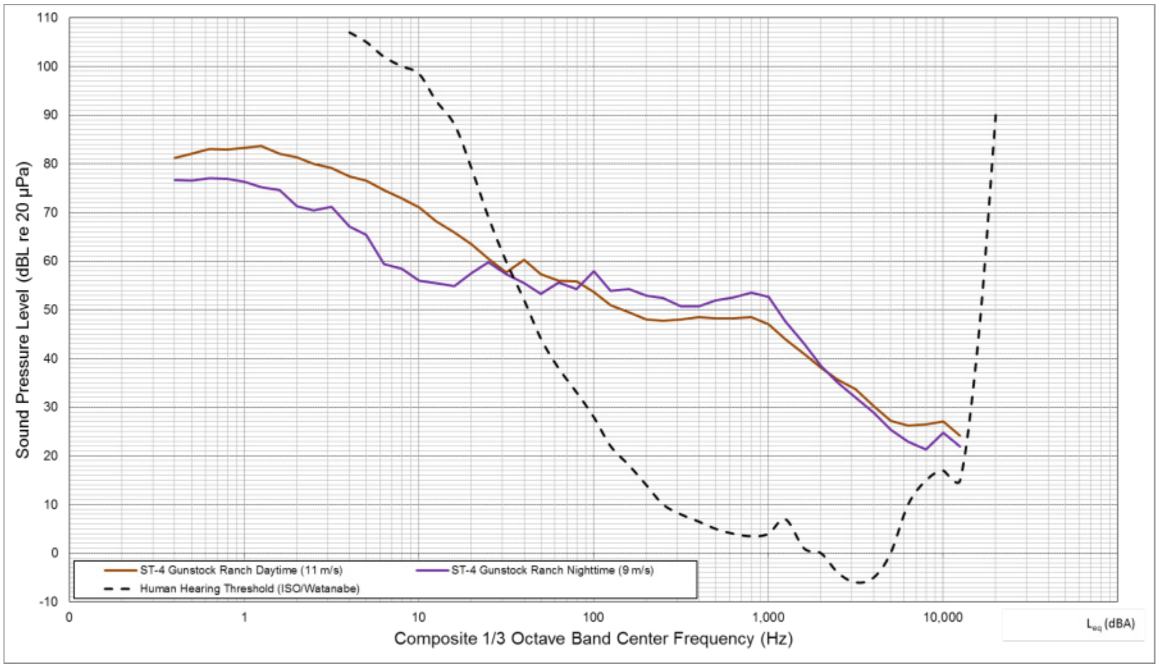

Figure 18. ST-4 1/3-Octave Band Spectral Plot

Monitoring Position: ST-5

Measurements at ST-5 were conducted on May 7, 2014 at the military entrance to the property which contains the Kahuku Wind Farm. The measurement was conducted to capture downwind sound levels from the Kahuku Wind Farm WTGs which are typically louder than in the upwind direction where the Project would be located. A daytime measurement was conducted from 10:00AM to 10:30AM and a nighttime measurement was conducted from 3:11AM to 3:41AM. Observed daytime sound sources included traffic on the Kamehameha Highway, the Kahuku Wind Farm WTGs, wind interacting vegetation, and periodic helicopter and fixed-wing aircraft flyovers. Nighttime observations included minimal traffic on the Kamehameha Highway, the Kahuku Wind Farm WTGs, wind interacting vegetation, and minimal insect noise. Hub height wind speeds during the daytime measurement were 5 m/s and were 6 m/s at night. The dominant sound source at night was from WTGs with the nearest WTG located 476m southwest. To characterize sound levels from just the WTGs to the extent possible was achieved by excluding one minute intervals which included a vehicle pass-by on the Kamehameha Highway. Figure 19 provides the 1/3-octave band spectral data for the daytime and nighttime monitoring periods as well as the nighttime period excluding vehicle pass-bys. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

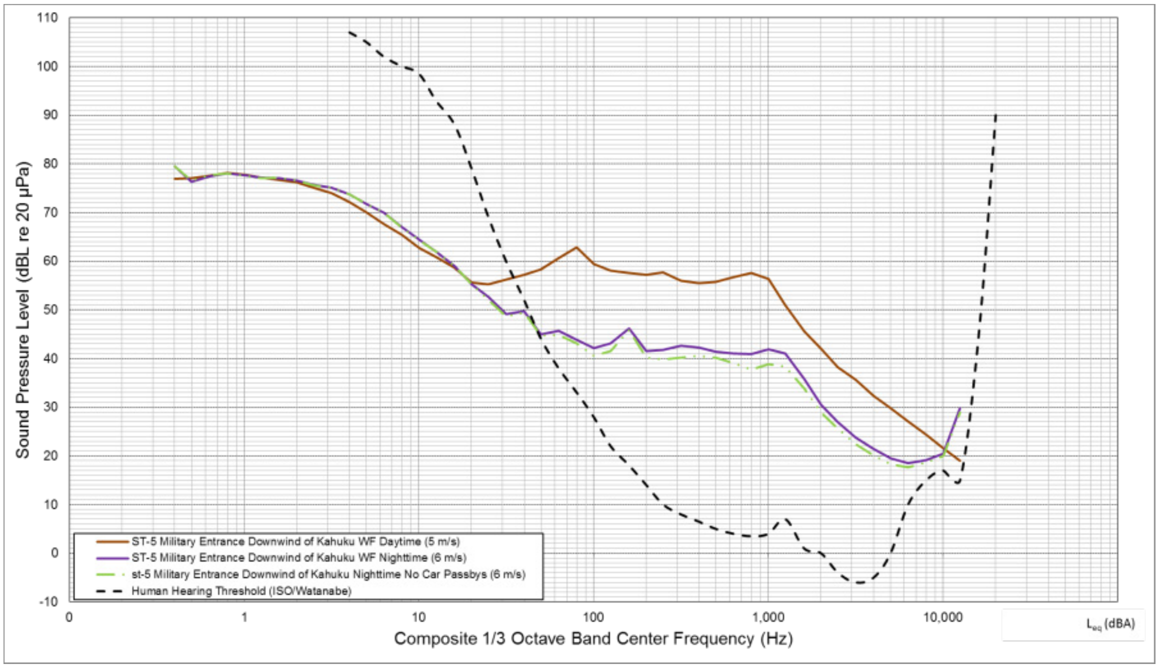

Figure 19. ST-5 1/3-Octave Band Spectral Plot

Monitoring Position: ST-6

The ST-6 measurement was conducted on May 7, 2014 3:54AM to 4:24AM along public ROW near leased DOA parcels that have single-family residences. The measurement was conducted to capture monitoring data at these residences where long-term equipment deployment was not allowed. ST-6 is meant to provide additional support data to characterize these DOA parcels that are located further from the existing Kahuku Wind Farm than those represented by ST-1. A nighttime measurement was conducted at ST-6 with observed sound sources including the existing WTGs at the Kahuku Wind Farm, wind interacting with vegetation, and limited insect noise. Traffic noise along the Kamehameha Highway was not audible during the measurement or was masked by other sounds including the existing WTGs. Figure 20 provides the 1/3-octave band spectral data for the monitoring period which included hub height wind speeds of 10 m/s. At no time were infrasound levels of sufficient strength to be above the threshold of human hearing.

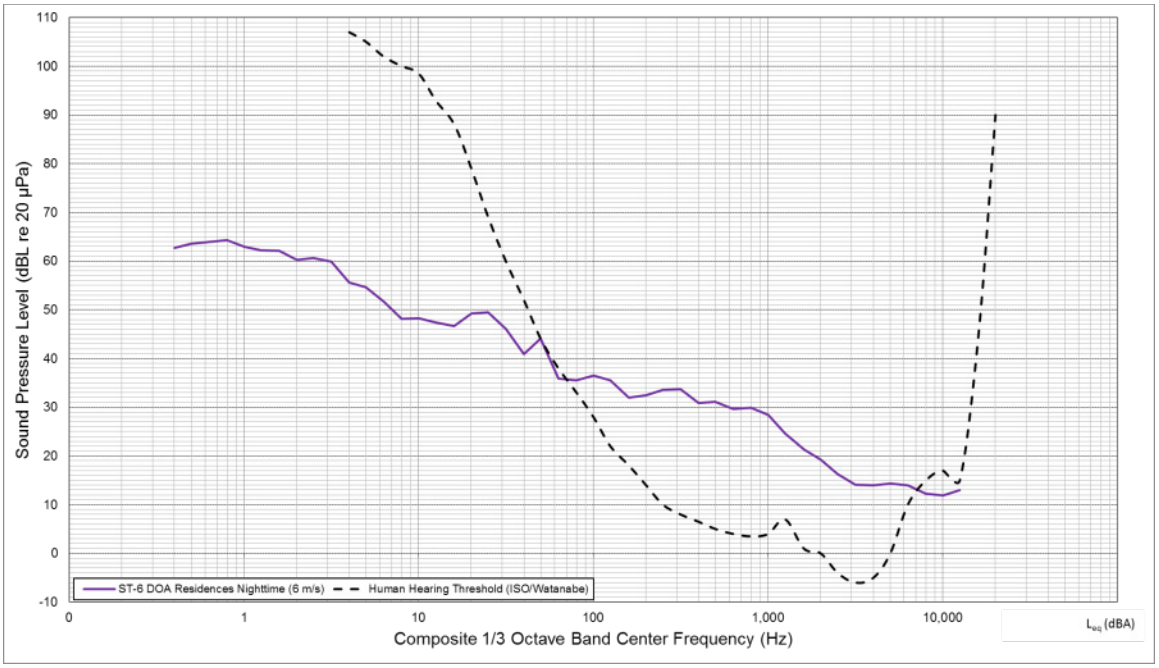

Figure 20. ST-6 1/3-Octave Band Spectral Plot

4.0 ACOUSTIC ANALYSIS METHODOLOGY

Each build alternative was evaluated for construction and operational noise impacts. The No Action Alternative, or Alternative 1, is not discussed here because there would be no noise, other than continued existing sound sources, associated with that alternative. There are two build alternatives under consideration, Alternative 2 (up to 25 MW) and Alternative 3 (up to 39 MW). Noise generated during Project construction and operation was assessed. Project construction was assessed in a semi-qualitative manner using information available at this stage of the design process and using representative equipment information where necessary. The operational acoustic assessment was completed using DataKustic GmbH's CadnaA, the computer-aided noise abatement program (v 4.4.145).

CadnaA is a comprehensive 3-dimensional acoustic software model that conforms to the Organization for International Standardization (ISO) standard ISO 9613-2 "Attenuation of Sound during Propagation Outdoors." The engineering methods specified in this standard consist of full (1/1) octave band algorithms that incorporate geometric spreading due to wave divergence, reflection from surfaces, atmospheric absorption, screening by topography and obstacles, ground effects, source directivity, heights of both sources and receptors, seasonal foliage effects, and meteorological conditions.

Atmospheric absorption depends on temperature and humidity and is most important at higher frequencies. Over short distances, the effects of atmospheric absorption are minimal. The ISO 9613-2 calculation calculates attenuation for meteorological conditions favorable to propagation, i.e., downwind sound propagation or what might occur typically during a moderate atmospheric ground level inversion, which is assumed to be regulatory worst case. An average temperature of 24° Celsius (75° Fahrenheit) and relative humidity of 67 percent was assumed, based on available yearly climate information for the Project Area. While site-specific meteorological data was considered in the acoustic assessment, it is important to note that atmospheric attenuation is not strongly dependent on temperature. Though a physical impracticality, the ISO 9613-2 standard simulates omnidirectional downwind propagation and maximum WTG source directivities. For receivers located between discrete WTG locations or WTG groupings, the acoustic model may result in over-prediction in sound level at receivers.

In addition to geometrical divergence, attenuation factors (A) include topographical features, terrain coverage, and/or other natural or anthropogenic obstacles that can affect sound attenuation and result in acoustical screening. Topographical information was imported into the acoustic model using the official U.S. Geological Survey (USGS) digital elevation dataset to accurately represent terrain in three dimensions. Terrain conditions, vegetation type, ground cover, and the density and height of foliage can also influence the absorption that takes place when sound waves travel over land. A mixed ground absorption rate was assumed with semi-reflective value of G=0.5 to represent the average ground absorption of the Project Area. Due to land elevation variability in proximity to the Project, additional conservative factors for sound propagation in complex terrain were also taken into account. Sound attenuation through foliage and diffraction around and over existing anthropogenic structures such as buildings were ignored under all acoustic modeling scenarios.

4.1 WIND TURBINE SOUND CHARACTERISTICS

There are two principal sound sources from an operating wind turbine: mechanical and aerodynamic sound. Mechanical sound is generated at the gearbox, generator, and cooling fan and is radiated from the surfaces of the nacelle and machinery enclosure and by openings in the nacelle casing. Aside from upset conditions that may result in abnormal mechanical noise emissions, the dominant noise generating component of utility scale wind turbines is aerodynamic.

Aerodynamic sound is related to air flow and the interaction with the tower structure and rotor blades when in motion and is the largest component of acoustic emissions for modern wind turbines. Sound originates from the flow of air around the air foils which is very strongly influenced by the tip speed of the blades. Tip speed is the speed of the tip of a rotor blade as it travels along the circumference of the rotor-swept area. The tip speed is directly related to the rotor size, which is fixed, and to the rotor rotational speed. The tip speed ratio is defined as the ratio of the speed of the tip of a rotating blade to the speed of the wind. Aerodynamic noise will vary primarily as a function of rotor rotational speed.

Air flow occurring across the blade produces turbulence at the surface boundary layer, which results in trailing edge boundary sound. Trailing edge sound is considered the principal aerodynamic noise source component of wind turbines. In addition to trailing edge, tip sound is created by vortex shedding as the blade tips pass through the air when in motion. Wind turbine manufacturers have instituted several measures to both reduce aerodynamic sound and increase power generation efficiency by reducing trailing edge and tip sound generation. Efforts to reduce aerodynamic sounds have included the use of upwind rotor designs, noise-reduced nacelle, variable speed operation resulting in lower tip speed ratios, and the use of specially modified rotor blades designed and fabricated to reduce trailing edge noise. Earlier wind turbine designs had the blades located downwind of the support structure. As the blades passed through the vortex shed behind the support tower, the blade would be momentarily displaced, resulting in a pressure pulse. This becomes the mechanism for the generation of excessive acoustic modulation and low frequency sound. The downwind rotor design is rarely used in modern utility-scale wind turbines that employ the now-standard upwind rotor design with blades upstream of the tower structure. This change in rotor location has greatly reduced many issues associated with the downwind design and resulted in a decrease of 10 dB or greater, which corresponds to a perceived decrease in loudness by a factor of two.

A somewhat unique acoustic characteristic of wind energy facilities is that the sound generated by each individual wind turbine will increase as the wind speed across the site increases, up to a certain maximum sound level reached at full rotation of the rotor blades (i.e., greater than approximately 8 meters per second [m/s]). All wind turbines under consideration for the Na Pua Makani Wind Farm are variable speed-type with sound predominantly determined by the aerodynamic broadband sound of the rotor blades, which is directly related to the circumferential or blade tip speed. Wind turbine sound is negligible when the rotor is at rest, increases as the rotor tip speed increases, and is generally constant once rated power output and full rotational speed is reached. As an offset, as wind speeds increase, the background ambient sound levels likely will continue to increase by the normal sound of wind blowing through trees and around buildings, resulting in acoustic masking effects. Aerodynamic noise is usually only perceived when the turbine rotor is moving and wind speeds are relatively low at ground level.

In order to assist project developers and acoustical engineers wind turbine manufacturers report WTG sound power levels at integer wind speeds referenced to the effective hub height, ranging from cut-in to full rated power per the International Electrotechnical Commission (IEC) 61400-11:2006 Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques. Table 13 presents a summary of sound power levels during normal mode operation. Sound power levels presented are inclusive of both mechanical and aerodynamic source components. The Vestas and Siemens specification present an expected warranty confidence interval (k-factor) of k=2 dB and k=1.5 dB, respectively. These k-factors were included in all acoustic modeling calculations and incorporates the uncertainty in independent sound power level measurements conducted, the applied probability level and standard deviation for test measurement reproducibility, and product variability. It is expected that the Vestas and Siemens WTGs installed would have similar sound profiles to what was used in the acoustic modeling analysis; however, it is possible that the final warranty sound data could vary slightly.

Table 13. Broadband Sound Power Levels (dBA) Reported in Accordance with IEC 61400-11

Wind Speed at Hub Height (AGL)	WTG Sound Power Level (LW) at Reference Wind Speed										
	7 mph (3 m/s)	9 mph (4 m/s)	11.2 mph (5 m/s)	13.4 mph (6 m/s)	15.9 mph (7 m/s)	17.9 mph (8 m/s)	20.1 mph (9 m/s)	22.4 mph (10 m/s)	24.6 mph (11 m/s)	26.8 mph (12 m/s)	29.1 mph (13 m/s)
Vestas V110-2.0	97.3	99.6	103.8	107.5	106.1	106.1	106.1	106.3	106.5	106.7	107
Siemens SWT 3.0-113	N/A	N/A	N/A	105	107.4	107.5	107.5	107.5	N/A	N/A	N/A

Source: Vestas 2013, Siemens 2013

A summary of sound power levels during full rotation for each turbine by octave band center frequency are presented in Table 14.

Table 14. Representative Octave Band 1/1 Center Frequencies

Frequency (Hz)	Octave Band Sound Power Level (dBA)								Broadband (dBA)
	63	125	250	500	1000	2000	4000	8000	
Vestas V110-2.0	89.9	94.5	97.2	99.6	102.2	100.7	99.1	92.3	107.5
Siemens SWT 3.0-113	85.5	93	100.4	103.7	100.4	92.5	81.6	78.3	107

Source: Vestas 2013, Siemens 2013

Predictions of WTG LFN and IS were conducted to identify potential impacts; however, these predictions are difficult for a number of reasons. For example, WTG manufacturers do not publish LFN and IS sound levels via their IEC 61400-11 testing reports; therefore, surrogate sound levels were needed to conduct the analysis. These surrogate values are the best available data, obtained from other published studies on Siemens WTGs. No data is known to exist on low LFN or IS source levels for Vestas wind turbines, but because the bulk of LFN and IS noise is a result of WTG blades the Siemens data is thought to be representative of the Vestas WTG as well. Additionally, attempts were made to scale the surrogate data to more closely match the Project WTG octave band spectra. Values used in the analysis of Project LFN and IS are given in Table 15.

Table 15. Representative Octave Band 1/1 LFN/IS Frequencies

Frequency (Hz)	Octave Band Sound Power Level (dBA)		
	8	16	31.5
Siemens SWT 3.0-113	59.8	73.7	84.8

Source: Scaled up from data in Epsilon 2010 using Siemens 2013 sound power data.

Another complication of LFN and IS prediction is that standard propagation modeling methodologies (e.g., ISO 9613-2) are not always appropriate because low frequency sounds attenuate at different rates with distance than the mid to high frequencies. Additionally, existing ambient LFN and IS are often already relatively high from the sounds of wind interacting with the environment vegetation or structures, vehicles on roadways, existing wind turbine noise from the Kahuku Wind Farm, and ocean waves crashing on shore. However, comparisons were made to existing LFN and IS levels to ascertain the net increase, if any, with the Project.

4.2 CONSTRUCTION NOISE

Construction noise analysis was evaluated for two Project build alternatives under consideration. Alternative 2 would implement two Vestas V110-2.0 and eight Siemens 3.0-113 WTGs. Alternative 3 would implement two Vestas V110-2.0 and 10 Siemens 3.0-113 WTGs.

4.2.1 Alternative 2

Construction of Alternative 2 would involve constructing of access roads, excavating and forming WTG foundations, works associated with preparing the site for crane-lifting, and actual WTG assembly and commissioning. Typically wind energy projects are constructed in four phases consisting of the following:

- **Site Clearing:** The initial site mobilization phase includes the establishment of temporary site offices, workshops, stores, and other on-site facilities. Installation of erosion and sedimentation control measures will be completed as well as the preparation of initial haulage routes.

- **Excavation:** This phase would begin with the excavation and formation of access roads and preparation of laydown areas. Excavation for the concrete WTG foundations would also be completed.
- **Foundation Work**: Construction of the reinforced concrete WTG foundations would take place in addition to installation of the internal transmission network.
- **Wind Turbine Installation**: Delivery of the WTG components would occur followed by their installation and commissioning.

Work on these construction activities is expected to overlap. It is likely that the WTGs would be erected in small groupings. Each grouping may undergo testing and commissioning prior to commencement of full commercial operation. Other construction activities include those for the supporting infrastructure such as the collection substation, maintenance building, and the overhead transmission lines. The construction of the Project may cause short-term but unavoidable noise impacts depending on the construction activity being performed and the distance to receiver. The sound levels resulting from construction activities vary significantly depending on several factors such as the type and age of equipment, the specific equipment manufacturer and model, the operations being performed, and the overall condition of the equipment and exhaust system mufflers. The list of construction equipment that may be used on the Project and estimates of near and far sound source levels are presented in Table 16.

Table 16. Alternative 2 Estimated L_{max} Sound Pressure Levels from Construction Equipment

Equipment*	Estimated Sound Pressure Level at 50 feet (dBA)	Estimated Sound Pressure Level at 2000 feet (dBA)
Forklift	80	48
Backhoe	80	48
Grader	85	53
Man basket	85	53
Dozer	83 - 88	51 - 56
Loader	83 - 88	51 - 56
Scissor Lift	85	53
Truck	84	52
Welder	73	41
Compressor	80	48
Concrete Pump	77	45

Sources: Federal Highway Administration, "Roadway Construction Noise Model User's Guide," Report FHWA-HEP-05-054 / DOT-VNTSC-FHWA-05-01, January 2006. Power Plant Construction Noise Guide, Bolt Beranek and Newman, Inc. 1977. Federal Highway Administration, "Procedures for Abatement of Highway Traffic Noise and Construction Noise." Code of Federal Regulations, Title 23, Part 772, 1992.

Sounds generated by construction activities would likely require a permit, to be obtained from the DOH, to allow for the operation of construction equipment that result in exceedances of the maximum permissible at property line locations. While the permit and permitting procedures do not limit the sound level generated at the construction site, time restrictions may be placed on time periods when the loudest construction activities are likely to occur, i.e. 7:00 a.m. and 7:00 p.m., Monday through Friday and between 9:00 a.m. and 6:00 p.m. on Saturday. The DOH would require reasonable and standard practices be employed to minimize the impact of noise resulting from construction activities. Provisions to conduct noise monitoring and community meetings may also be required, but will likely be deemed unnecessary given the remote location.

The Project would proactively work with the community and attempt to resolve any complaints or concerns due to noise from construction by coordinating activities and informing the community of the timing of the expected construction noise at the closest NSRs to avoid conflicts, i.e., if blasting for foundation or removal of ledge or other potentially noisy activities are required during the construction period, nearby residents shall be notified in advance.

Construction activity would generate traffic having potential noise effects, such as trucks travelling to and from the site on public roads. Traffic noise is categorized into two categories: (1) the noise that will occur during the initial temporary traffic movements related to turbine delivery, haulage of components and remaining construction; and (2) maintenance and ongoing traffic from staff and contractors, which is expected to be minor. At the early stage of the construction phase, equipment and materials would be delivered to the site, such as hydraulic excavators and associated spreading and compacting equipment needed to form access roads and foundation platforms for each turbine. Once the access roads are constructed, equipment for lifting the towers and turbine components would arrive. Concrete would be mixed offsite and delivered to the Project site, rather than produced by an on-site concrete batch plant.

Federal laws prohibit state and local governments from regulating off-site sound levels generated by trucks and automobiles operating on a private site or public roadways. This federal regulatory preemption is specified in the Federal Noise Control Act of 1972 and in the Surface Transportation Assistance Act of 1982, both of which prohibit states and local authorities from regulating the noise emitted by trucks engaged in interstate commerce, i.e., truck deliveries. A federal OSHA preemption also prohibits local and state governments from regulating safety signals on trucks and construction equipment. Alternative 2 construction would be coordinated with individual landowners regarding the operation of trucks, cars and other vehicles on private site access roadways as necessary to prevent the occurrences of unexpected noise resulting from construction and transport related vehicle movements.

4.2.2 Alternative 3

The first phase of construction of Alternative 3 would be identical to Alternative 2 and the second phase of Alternative 3 would use an identical method as that for the first phase of construction. The variation in construction noise between phases one and two of construction are a result of where construction would take place and that construction would occur at least two years later for the second phase. Like Alternative 2, construction noise is likely to exceed HAR 11-46 limits at some TMKs in the Project Area and therefore a permit from the DOH would likely be required. Mitigation of construction noise would be the same for Alternative 3 as that for Alternative 2.

4.3 OPERATIONAL NOISE

Operational noise analysis was conducted for the same two Project alternatives under consideration (e.g., Alternatives 2 and 3) and for the two WTG types under consideration.

4.3.1 Alternative 2

Operational noise with implementation of Alternative 2 would result from the WTGs and to a lesser extent the proposed substation 50 MVA transformer. Operational broadband (dBA) sound pressure levels were calculated assuming that all Alternative 2 WTGs would be operating continuously and concurrently at the highest manufacturer-rated sound level at the given operational condition. The sound energy was then summed to determine the equivalent continuous A-weighted downwind sound pressure level at a point of compliance with HAR 11-46, in this case the property or TMK limit. Calculations were completed along each property limit in the acoustic analysis area at a height of 5 ft (1.52 m) above ground (the approximate height of ears of a standing person). This is also the standard height at which testing for compliance with the State Community Noise Control Rule is completed. Table 17 presents the range of sound levels received at each TMK zoning class along the property line in the acoustic analysis area. These predictions demonstrate that compliance with HAR 11-46 is achieved since Project operational sound levels at the receiving property lines are at or below the controlling noise limit for each zone. Figure 21 provides a map of received sound levels in the acoustic analysis area for Alternative 2.

Table 17. Alternative 2 Range of Property Line Received Sound Levels by HAR 11-46 Zoning Class

HAR 11-46 Zoning Class	Controlling HAR 11-46 Zoning Limit (dBA L_{eq})	Range of Received Sound Levels dBA L_{eq}
Class A	45	8 - 43
Class B	50	37 - 40
Class A (Day Only)*	55	29 – 43
Class C	70	9 - 59

Note: *Class A (Day Only) uses include those at the area schools and golf course.

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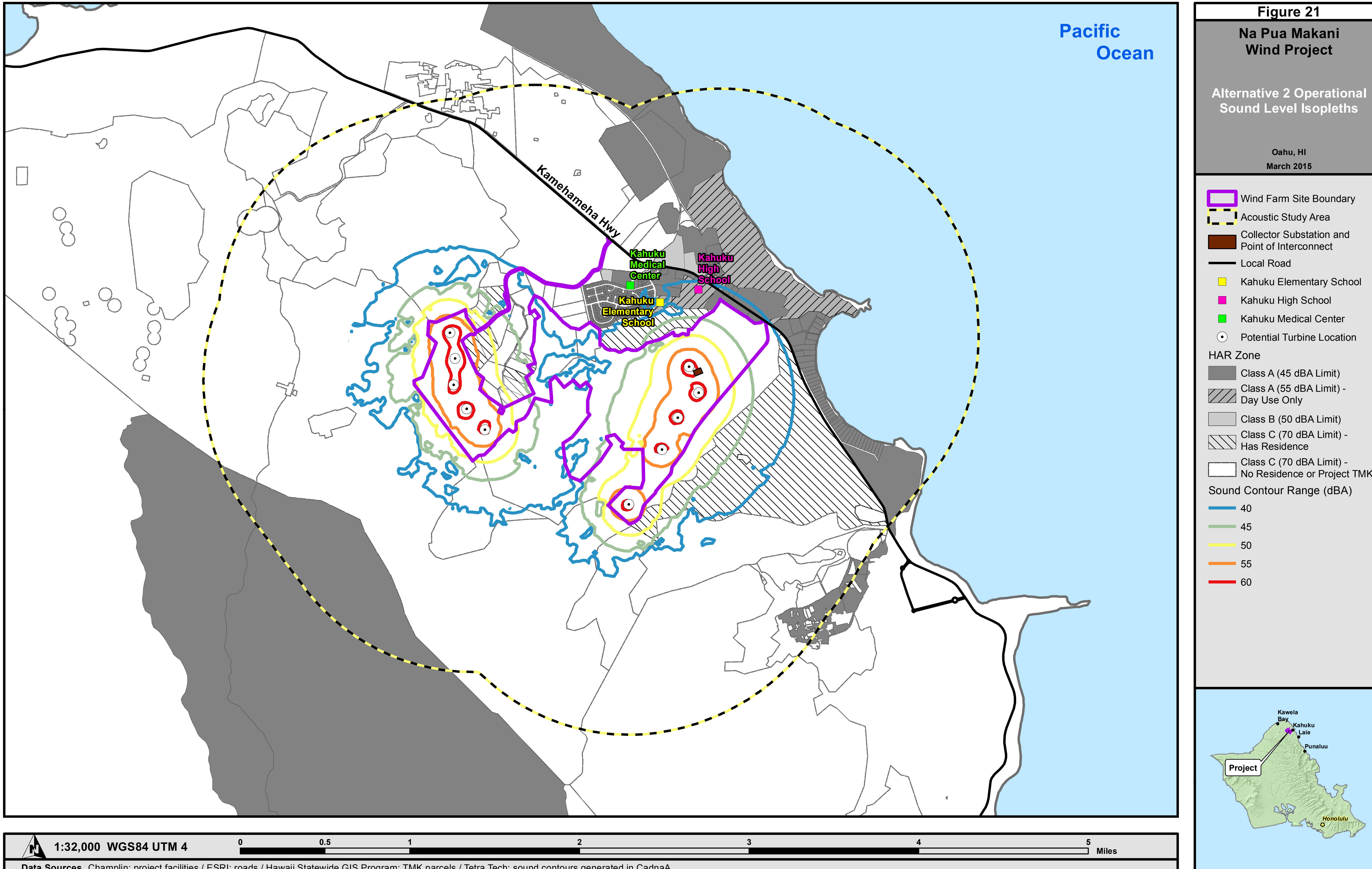


1:32,000 WGS84 UTM 4

0 0.5 1 2 3 4 5 Miles

Data Sources Champlin: project facilities / ESRI: roads / Hawaii Statewide GIS Program: TMK parcels / Tetra Tech: sound contours generated in CadnaA

P:\GIS_PROJECTS\Champlin_Wind\Na_Pua_Makani\MXDs\EIS\DEIS\Report_Figures\NoiseImpactAssessment\Champlin_NaPuaMakani_DEIS_Sound_Fig21_Alt2_11i17t_20150325.mxd - Last Saved 12/5/2014

LFN/IS Predictions

As indicated in the regulatory environment description in this document (Section 2.0) there are no federal, state, or local regulations that stipulate LFN/IS noise level limits. Nevertheless, because the community has indicated concern via comments received during scoping, Champlin elected to analyze the contribution of predicted Project LFN/IS to existing LFN/IS levels in order to ascertain if there could be potential Project-related LFN/IS impacts. The analysis was conducted at the nearest NSRs to the Project's WTGs to determine if LFN/IS would exceed the threshold of human hearing, the DEFRA limits, and/or the ANSI S12.9 Part 4 guidelines. The nearest residence is located approximately 673 feet (205 meters) a proposed WTG. Received LFN/IS are predicted to be 83 dB at 8 Hz and 76 dB at 16 Hz which are both well below the threshold of human hearing and the DEFRA limits but higher than the ANS S12.9 Part 4 guideline of 65 dB at 16 Hz. Monitored sound levels in this area would be similar to those monitored at positions LT-1 and ST-1 which shows that existing LFN/IS sound levels range from 69-76 dB at 8 Hz and 63-71 at 16 Hz, all below the threshold of human hearing, but at 16 Hz baseline sound levels are on average above the ANSI S12.9 Part 4. The Project would result in an increase in LFN/IS of but much of this would be masked by existing sound levels. Regardless, because it is unlikely that Project LFN/IS would be audible at these frequencies even the highest increases of LFN/IS would not result in an impact at the nearest residence. With regard to the 65 dB ANSI S12.9 Part 4 guideline, because the baseline sound levels are already above this threshold the likelihood of complaints is low given that Project LFN/IS would also be partially masked. Therefore, there is no anticipated LFN/IS impact from Alternative.

4.3.2 Alternative 3

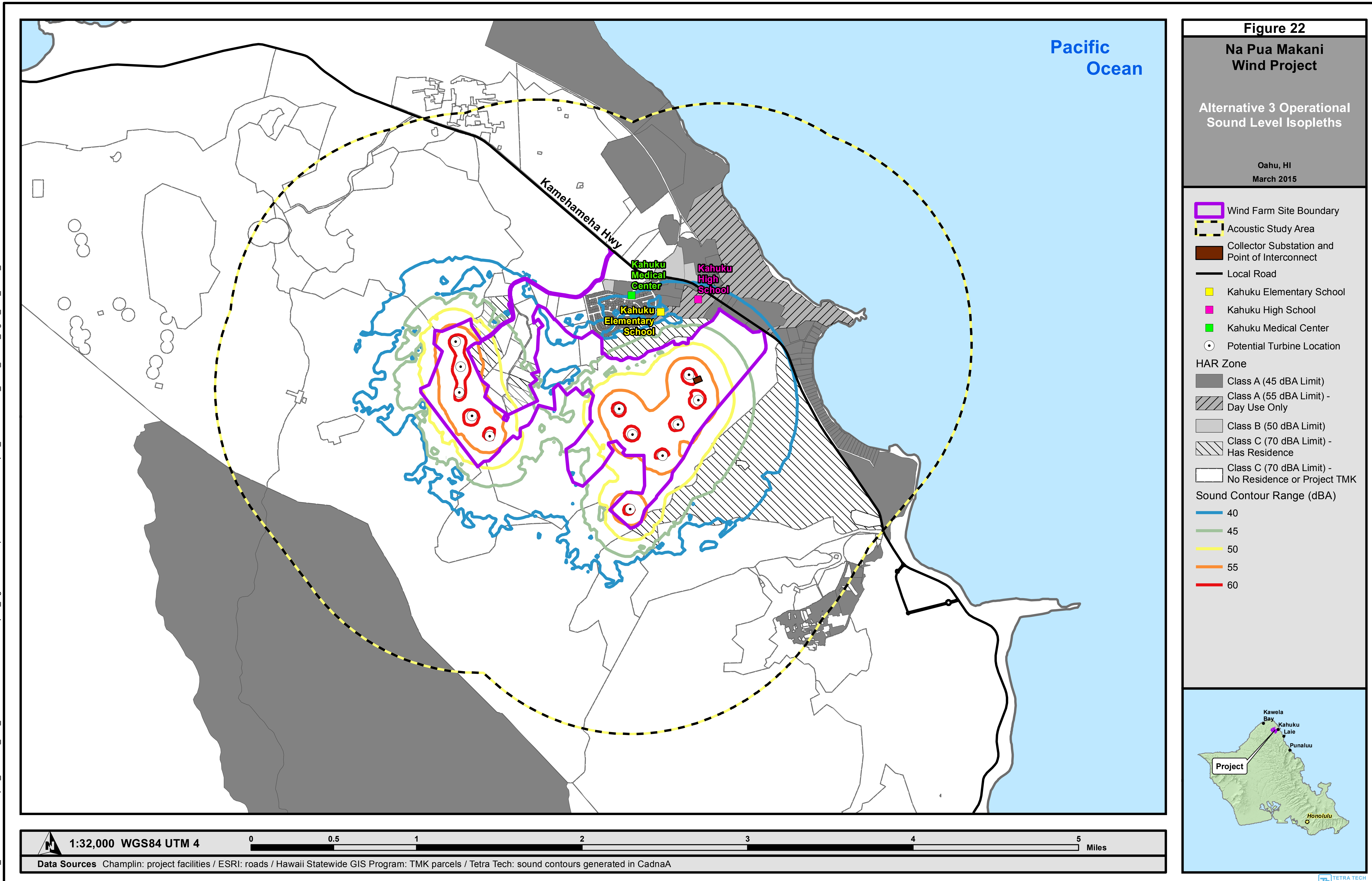
Operational noise with implementation of Alternative 3 would result from WTGs and to a lesser extent the proposed substation 50 MVA transformer. Additionally, the worst case LFN/IS noise levels would be the same under Alternative 3 as they are under Alternative 2 because the nearest residence is the same for the alternative being located 205 meters from the nearest proposed turbine. Refer to the Alternative 2 discussion of LFN/IS for results.

Operational broadband (dBA) sound pressure levels were calculated assuming that all Alternative 3 WTGs (a total of 13) would be operating continuously and concurrently at the maximum manufacturer-rated sound level at the given operational condition. The sound energy was then summed to determine the equivalent continuous A-weighted downwind sound pressure level at a point of compliance with HAR 11-46, in this case the property or TMK limit. Calculations were completed using receptor points along each property limit in the acoustic analysis area at a height of 5 ft (1.52 m) above ground (the approximate height of ears of a standing person). This is also the standard height at which testing for compliance with the State Community Noise Control Rule is completed. Table 19 presents the range of sound levels received at each TMK zoning class along the property line in the acoustic analysis area. Compliance with HAR 11-46 is achieved if Project operational sound levels at the receiving property line are at or below the controlling noise limit for each zone. Because sound levels for operation of the Project are all below the controlling HAR 11-46 limit the Project is anticipated to be in compliance.

Table 19. Alternative 3 Range of Property Line Received Sound Levels by HAR 11-46 Zoning Class

HAR 11-46 Zoning Class	Controlling HAR 11-46 Zoning Limit (dBA L_{eq})	Range of Received Sound Levels dBA L_{eq}
Class A	45	9 – 44
Class B	50	37 – 40
Class A (Day Only)*	55	30 – 43
Class C	70	10 – 59

Note: *Class A (Day Only) uses include those at the area schools and golf course.



Pacific Ocean
Kamehameha Hwy
Kahuku Medical Center
Kahuku High School
Kahuku Elementary School
Figure 22
Na Pua Makani Wind Project
Alternative 3 Operational Sound Level Isopleths
Oahu, HI
March 2015
Wind Farm Site Boundary
Acoustic Study Area
Collector Substation and Point of Interconnect
Local Road
Kahuku Elementary School
Kahuku High School
Kahuku Medical Center
Potential Turbine Location
HAR Zone
Class A (45 dBA Limit)
Class A (55 dBA Limit) - Day Use Only
Class B (50 dBA Limit)
Class C (70 dBA Limit) - Has Residence
Class C (70 dBA Limit) - No Residence or Project TMK
Sound Contour Range (dBA)
40
45
50
55
60
Kawela Bay
Kahuku
Laie
Punaluu
Project
Honolulu
1:32,000 WGS84 UTM 4
0
0.5
1
2
3
4
5
Miles
Data Sources Champlin: project facilities / ESRI: roads / Hawaii Statewide GIS Program: TMK parcels / Tetra Tech: sound contours generated in CadnaA
P:\GIS_PROJECTS\Champlin_Wind\Na_Pua_Makani\MXDs\EIS\DEIS\Report_Figures\NoiseImpactAssessment\Champlin_NaPuaMakani_DEIS_Sound_Fig22_Alt3_11i17i_20150325.mxd - Last Saved 3/25/2015
TETRA TECH

5.0 CONCLUSIONS

To conclude, Alternative 2 results in lower overall sound levels than Alternative 3 due to the smaller number of WTGs being constructed and operated. Both Alternatives would be able to be constructed in compliance with HAR 11-46, but only if the construction contractor obtains a noise permit from DOH. Operationally neither Alternative is predicted to exceed the HAR 11-46 sound level limits, but both alternatives are predicted to increase sound levels in the acoustic analysis area by greater than 2 dBA at some Zone A or B TMKs, therefore operationally both Alternatives are similar although Alternative 3 results in slightly higher noise levels than Alternative 2. LFN/IS are not predicted to be a concern for the Project and are predicted to be below the threshold of human hearing. Additionally, there have been no known scientifically peer reviewed studies to date concluding a relationship between LFN and IS to health effects. Even so, the LFN/IS sound levels predicted with the Project are considered low level as they are below the threshold of human hearing and are not thought to pose a health risk to humans. Furthermore, monitored ambient LFN/IS levels would mask some of the Project LFN/IS further reducing the potential for public complaint. Nevertheless, to respond to potential future public concerns Champlin may decide to implement a noise complaint resolution process. This process might include a post construction sound survey to ascertain the net increase, if any, in sound levels in the acoustic analysis area. Regardless, because there are no predicted operational noise impacts, mitigation of operational noise is not necessary.

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APPENDIX A CALIBRATION SHEETS

Certificate of Calibration and Conformance

This document certifies that the instrument referenced below meets published specifications per Procedure PRD-P263; ANSI S1.4-1983 (R 2006) Type 1; S1.4A-1985; S1.43-1997 Type 1; S1.11-2004 Octave Band Class 0; S1.25-1991; IEC 61672-2002 Class 1; 60651-2001 Type 1; 60804-2000 Type 1; 61260-2001 Class 0; 61252-2002.

Manufacturer:	Larson Davis	Temperature:	72.6	°F
Model Number:	831		22.56	°C
Serial Number:	3140	Rel. Humidity:	10.9	%
Customer:	TMS Rental	Pressure:	1004.1	mbars
Description:	Sound Level Meter		1004.1	hPa

Note: As Found / As Left: In Tolerance

Upon receipt for testing, this instrument was found to be:

Within the Stated tolerance of the manufacturer's specification

Calibration Date: 29-Jan-14 Calibration Due:

Calibration Standards Used:

Manufacturer	Model	Serial Number	Cal Due	Traceability No.
Larson Davis	LDSigGen/2239	0760/0109	4/12/2014	2012-161465

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at The Modal Shop and/or Larson Davis Corporate Headquarters. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

This calibration complies with ISO 17025 and ANSI Z540. The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. Calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of The Modal Shop.

Technician: Wayne Underwood Signature:

THE MODAL SHOP INC.
A PCB GROUP CO.

The Modal Shop, Inc.
3149 East Kemper Road
Cincinnati, OH 45241
Phone: (513) 351-9919
(800) 860-4867
www.modalshop.com

PRD-F242 revNR December 2, 2008 Page 1 of 1

PCB PIEZOTRONICS
A PCB GROUP COMPANY

Certificate of Calibration and Conformance

Certificate Number 2013-175223

Instrument Model 831, Serial Number 0001350, was calibrated on 10JUN2013. The instrument meets factory specifications per Procedure D0001.8310, ANSI S1.4-1983 (R 2006) Type 1; S1.4A-1985 ; S1.43-1997 Type 1; S1.11-2004 Octave Band Class 1; S1.25-1991; IEC 61672-2002 Class 1; 60651-2001 Type 1; 60804-2000 Type 1; 61260-2001 Class 1; 61252-2002.

Instrument found to be in calibration as received: YES
Date Calibrated: 10JUN2013
Calibration due: 10JUN2015

Calibration Standards Used

MANUFACTURER	MODEL	SERIAL NUMBER	INTERVAL	CAL. DUE	TRACEABILITY NO.
Stanford Research Systems	DS360	61746	12 Months	06JUL2013	61746-070612

Reference Standards are traceable to the National Institute of Standards and Technology (NIST)

Calibration Environmental Conditions

Temperature: 24 ° Centigrade

Relative Humidity: 32 %

Affirmations

This Certificate attests that this instrument has been calibrated under the stated conditions with Measurement and Test Equipment (M&TE) Standards traceable to the U.S. National Institute of Standards and Technology (NIST). All of the Measurement Standards have been calibrated to their manufacturers' specified accuracy / uncertainty. Evidence of traceability and accuracy is on file at Provo Engineering & Manufacturing Center. An acceptable accuracy ratio between the Standard(s) and the item calibrated has been maintained. This instrument meets or exceeds the manufacturer's published specification unless noted.

The collective uncertainty of the Measurement Standard used does not exceed 25% of the applicable tolerance for each characteristic calibrated unless otherwise noted.

The results documented in this certificate relate only to the item(s) calibrated or tested. A one year calibration is recommended, however calibration interval assignment and adjustment are the responsibility of the end user. This certificate may not be reproduced, except in full, without the written approval of the issuer.

"AS RECEIVED" data same as shipped data.
Tested with PRM831-010875

Signed: Ron Harris
Technician: Ron Harris

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Provo Engineering and Manufacturing Center, 1681 West 820 North, Provo, Utah 84601
Toll Free: 888.258.3222 Telephone: 716.926.8243 Fax: 716.926.8215
ISO 9001-2008 Certified

Scantek, Inc.
CALIBRATION LABORATORY

NVLAP®

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP Lab Code: 200625-0

Calibration Certificate No.30716

Instrument: **Sound Level Meter**
Model: **140**
Manufacturer: **Norsonic**
Serial number: **1402796**
Tested with: **Microphone 1225 s/n 112883**
Preamplifier 1209 s/n 13442
Type (class): **1**
Customer: **Scantek, Inc.**
Tel/Fax: **410-290-7726 / 410-290-9167**

Date Calibrated: **3/3/2014** *Cal Due:* **3/4/2015**

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No
Calibration service: __ Basic _X_ Standard
Address: **6430 Dobbin Road, Suite C, Columbia, MD 21045**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/22/2012
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31052	Oct 7, 2013	Scantek, Inc./ NVLAP	Oct 7, 2014
DS-360-SRS	Function Generator	33584	Sep 30, 2013	ACR Env./ A2LA	Sep 30, 2015
34401A-Agilent Technologies	Digital Voltmeter	US36120731	Sep 30, 2013	ACR Env. / A2LA	Sep 30, 2014
HM30-Thommen	Meteo Station	1040170/39633	Sep 30,2013	ACR Env./ A2LA	Sep 30, 2014
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 8, 2013	Scantek, Inc./ NVLAP	Nov 8, 2014

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
24.4 °C	101.260 kPa	34.1 %RH

Calibrated by:	Lydon Dawkins	Authorized signatory:	Mariana Buzduga
Signature	Lydon Dawkins	Signature	[signature]
Date	3/3/2014	Date	3/5/2014

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
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Results summary: Device complies with following clauses of mentioned specifications:

CLAUSES [1] FROM IEC/ANSI STANDARDS REFERENCED IN PROCEDURES:	RESULT[2,3]	EXPANDED UNCERTAINTY (coverage factor 2) [dB]
CALIBRATION OF SOUND LEVEL METER - ANSI S1.4 CLAUSE 3.2	Passed	0.2
LEVEL LINEARITY TEST - ANSI S1.4-1983, CLAUSE 6.9 & 6.10	Passed	0.25
WEIGHTING NETWORK TEST: A NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
WEIGHTING NETWORK TEST: C NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
WEIGHTING NETWORK TEST: LINEAR NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
OVERLOAD DETECTOR TEST: A-NETWORK - ANSI S1.4-1983 CLAUSE 8.3.1	Passed	0.25
F/S/I/PEAK TEST: STEADY STATE RESPONSE - ANSI S1.4 1983 CLAUSE 6.4	Passed	0.25
FAST-SLOW TEST: OVERSHOOT TEST - ANSI S1.4 1983 CLAUSE 8.4.1	Passed	0.25
FAST-SLOW TEST: SINGLE SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.1 & 8.4.3	Passed	0.25
IMPULSE TEST: CONTINUOUS SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.3	Passed	0.25
IMPULSE TEST: SINGLE SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.1 & 8.4.3	Passed	0.25
PEAK DETECTOR TEST, SINGLE SQUARE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.4	Passed	0.25
RMS DETECTOR TEST: CREST FACTOR TEST - ANSI S1.4-1983 CLAUSE 8.4.2	Passed	0.25
RMS DETECTOR TEST: CONTINUOUS SINE WAVE BURST - ANSI S1.4-1983 CLAUSE 8.4.2	Passed	0.25
TIME AVERAGING TEST: AVERAGING FUNCTIONS - ANSI S1.43 CLAUSE 9.3.2	Passed	0.25
LINEARITY TEST - ANSI S1.43 CLAUSE 9.3.3	Passed	0.15
FILTER TEST 1/1OCTAVE: RELATIVE ATTENUATION - IEC 61260, CLAUSE 4.4 & #5.3	Passed	0.25
FILTER TEST 1/3OCTAVE: RELATIVE ATTENUATION - IEC 61260, CLAUSE 4.4 & #5.3	Passed	0.25
SUMMATION OF ACOUSTIC TESTS - ANSI S1.4 CLAUSE 5 USING ACTUATOR	Passed	0.2-0.5

1 The results of this calibration apply only to the instrument type with serial number identified in this report.
2 Parameters are certified at actual environmental conditions.
3 The tests marked with (*) are not covered by the current NVLAP accreditation.

Comments: The instrument was tested and met all specifications found in the referenced procedures.

Note: The instrument was tested for the parameters listed in the table above, using the test methods described in the listed standards. All tests were performed around the reference conditions. The test results were compared with the manufacturer's or with the standard's specifications, whichever are larger.
Compliance with any standard cannot be claimed based solely on the periodic tests.

Tests made with the following attachments to the instrument:

Microphone:	Norsonic 1225 s/n 112883 for acoustical test
Preamplifier:	Norsonic 1209 s/n 13442 for all tests
Other: line adaptor ADP005 (18pF) for electrical tests	
Accompanying acoustical calibrator:	none
Windscreen:	none

Measured Data: in Test Report # 30713 of 12 + 1 pages.

Place of Calibration: Scantek, Inc.
6430 Dobbin Road, Suite C
Columbia, MD 21045 USA
Ph/Fax: 410-290-7726/ -9167
callab@scantekinc.com

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Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC and APLAC signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.27879

Instrument:	**Sound Level Meter**	*Date Calibrated:* **5/8/2013**	*Cal Due:* **5/9/2014**
Model:	**140**		
Manufacturer:	**Norsonic**		
Serial number:	**1403045**		
Tested with:	**Microphone 1225 s/n 91814**		
	Preamplifier 1209 s/n 12742		
Type (class):	**1**		
Customer:	**Scantek, Inc.**	*Address:*	**6430 Dobbin Road, Suite C, Columbia, MD 21045**
Tel/Fax:	**410-290-7726 / 410-290-9167**		

Status:	**Received**	**Sent**
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No
Calibration service: __ Basic _X_ Standard

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/22/2012
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31052	Sep 14, 2012	Scantek, Inc./ NVLAP	Sep 14, 2013
DS-360-SRS	Function Generator	33584	Sep 9, 2011	ACR Env./ A2LA	Sep 9, 2013
34401A-Agilent Technologies	Digital Voltmeter	US36120731	Sep 12, 2012	ACR Env. / A2LA	Sep 12, 2013
HM30-Thommen	Meteo Station	1040170/39633	Dec 6, 2012	ACR Env./ A2LA	Dec 6, 2013
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Dec 14, 2012	Scantek, Inc./ NVLAP	Dec 14, 2013

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
22.9 °C	100.010 kPa	51.5 %RH

Calibrated by:	Mariana Buzduga	**Authorized signatory:**	Valentin Buzduga
Signature		Signature	
Date	5/9/2013	Date	5/09/2013

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
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Results summary: Device complies with following clauses of mentioned specifications:

CLAUSES[1] FROM IEC/ANSI STANDARDS REFERENCED IN PROCEDURES:	RESULT[2,3]	EXPANDED UNCERTAINTY (coverage factor 2) [dB]
CALIBRATION OF SOUND LEVEL METER - ANSI S1.4 CLAUSE 3.2	Passed	0.2
LEVEL LINEARITY TEST - ANSI S1.4-1983, CLAUSE 6.9 & 6.10	Passed	0.25
WEIGHTING NETWORK TEST: A NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
WEIGHTING NETWORK TEST: C NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
WEIGHTING NETWORK TEST: LINEAR NETWORK - ANSI S1.4-1983 CLAUSE 8.2.1	Passed	0.25
OVERLOAD DETECTOR TEST: A-NETWORK - ANSI S1.4-1983 CLAUSE 8.3.1	Passed	0.25
F/S/I/PEAK TEST: STEADY STATE RESPONSE - ANSI S1.4 1983 CLAUSE 6.4	Passed	0.25
FAST-SLOW TEST: OVERSHOOT TEST - ANSI S1.4 1983 CLAUSE 8.4.1	Passed	0.25
FAST-SLOW TEST: SINGLE SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.1 & 8.4.3	Passed	0.25
IMPULSE TEST: CONTINUOUS SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.3	Passed	0.25
IMPULSE TEST: SINGLE SINE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.1 & 8.4.3	Passed	0.25
PEAK DETECTOR TEST, SINGLE SQUARE WAVE BURST - ANSI S1.4 1983 CLAUSE 8.4.4	Passed	0.25
RMS DETECTOR TEST: CREST FACTOR TEST - ANSI S1.4-1983 CLAUSE 8.4.2	Passed	0.25
RMS DETECTOR TEST: CONTINUOUS SINE WAVE BURST - ANSI S1.4-1983 CLAUSE 8.4.2	Passed	0.25
TIME AVERAGING TEST: AVERAGING FUNCTIONS - ANSI S1.43 CLAUSE 9.3.2	Passed	0.25
LINEARITY TEST - ANSI S1.43 CLAUSE 9.3.3	Passed	0.15
FILTER TEST 1/1OCTAVE: RELATIVE ATTENUATION - IEC 61260, CLAUSE 4.4 & #5.3	Passed	0.25
FILTER TEST 1/3OCTAVE: RELATIVE ATTENUATION - IEC 61260, CLAUSE 4.4 & #5.3	Passed	0.25
SUMMATION OF ACOUSTIC TESTS - ANSI S1.4 CLAUSE 5 USING ACTUATOR	Passed	0.2-0.5

1 The results of this calibration apply only to the instrument type with serial number identified in this report.

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Comments: The instrument was tested and met all specifications found in the referenced procedures.

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Tests made with the following attachments to the instrument:

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Preamplifier: Norsonic 1209 s/n 12742 for all tests
Other: line adaptor ADP005 (18pF) for electrical tests
Accompanying acoustical calibrator: none
Windscreen: none

Measured Data: in Test Report # 27879 of 12+1 pages.

Place of Calibration: Scantek, Inc.
6430 Dobbin Road, Suite C
Columbia, MD 21045 USA

Ph/Fax: 410-290-7726/ -9167
callab@scantekinc.com

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